Atomic Energy Control Board
P O Box 1046
Ottawa Canada
K1P 5S9

Commission de contrôle de l'énergie atomique
C P 1046
Ottawa Canada
K1P 5S9

92-07288/ INFO-0349

LINK BETWEEN ORE BODIES AND BIOSPHERE CONCENTRATIONS OF URANIUM

(AECB Project No.5.140.1)

by

S. Gordon

A research report prepared for the
Atomic Energy Control Board
Ottawa, Canada

Published January 1992

Canada

Research report

LINK BETWEEN ORE BODIES AND BIOSPHERE CONCENTRATIONS OF URANIUM

A report by Sue Gordon, under contract to the Atomic Energy Control Board.

ABSTRACT

A literature review of uranium exploration studies was carried out to determine the size and concentration of uranium anomalies in the biosphere. Fourteen sites were studied and uranium data were obtained for rocks, water-borne sediments, surface waters, groundwaters, soils and plants. Detailed descriptions of the study areas and of their uranium anomalies are provided. No statistical analyses of the data of anomaly sizes was undertaken because of the variation in the scale of the studies and in the threshold values used and the small number of samples for each medium. The threshold values and the size of the anomaly were found to be dependent on the scale of the study and of the sampling density.

Sediments and surface waters were found to have the largest uranium dispersion. Although there was a wide range in the anomaly sizes it was possible to assign typical values for each medium. Based on a typical source of 1 km^2 in the rock it was found that anomalies of similar size as the source are expected in soils and plants, anomalies twice as large are typical for sediments and surface waters and anomalies of smaller areas than the source are possible for groundwater. Some limitations to providing typical groundwater anomaly sizes are outlined. Typical maximum concentrations for the sites studied were greater than 1300 ppm for rock, 10 to 110 ppm for sediment, and 5 ppb for surface waters. No typical values were observed for groundwater, soils and plants. Susceptibility of the host rock to leaching and the presence of discharge zones were assessed for their role in biosphere anomalies.

RÉSUMÉ

Un examen de la documentation existante sur l'exploration minière de l'uranium a été entrepris pour déterminer la taille et la concentration des anomalies d'uranium dans la biosphère. Quatorze sites ont été examinés et des données sur l'uranium ont été obtenues pour les roches, les sédiments transportés par l'eau, les

eaux de surface, les eaux souterraines, les sols et les plantes. Des descriptions détaillées des zones à l'étude et de leurs anomalies d'uranium sont fournies. Aucune analyse statistique des données sur la taille des anomalies n'a été entreprise parce que l'échelle des études et les valeurs de seuil utilisées variaient, et qu'il y avait peu d'échantillons de chaque médium. On a découvert que les valeurs de seuil et la taille de l'anomalie dépendaient de l'échelle de l'étude et de la densité des échantillons.

On a aussi découvert que les sédiments et les eaux de surface contenaient le plus d'uranium. Bien que la taille des anomalies fût très variable, il a été possible de déterminer des valeurs typiques pour chaque médium. À partir d'une source de référence de 1 km² dans la roche, on a découvert que l'on peut s'attendre à ce que des anomalies de taille semblable à la source existent dans les sols et les plantes, que des anomalies deux fois plus grandes sont typiques dans les sédiments et les eaux de surface, tandis que des anomalies plus petites que la source sont possibles dans les eaux souterraines. Les quelques limitations éprouvées pour fournir des indications sur la taille typique des anomalies des eaux souterraines sont fournies. Les concentrations maximales typiques des sites à l'étude étaient supérieures à 1300 parties par million dans la roche, variaient de 10 à 110 parties par million dans les sédiments et dépassaient 5 parties par milliard dans les eaux de surface. On n'a observé aucune valeur typique pour les eaux souterraines, les sols et les plantes. La susceptibilité de la roche hôte à la lixiviation et la présence de zones de décharge ont été évaluées pour déterminer leur rôle par rapport aux anomalies dans la biosphère.

DISCLAIMER

The Atomic Energy Control Board is not responsible for the accuracy of the statements made or opinions expressed in this publication, and neither the Board nor the authors assume liability with respect to any damage or loss incurred as a result of the use made of the information contained in this publication.

TABLE OF CONTENTS

		Page
ABSTRACT		
LIST OF TABLES		iv
1.0	Introduction	1
2.0	Description of the Biosphere Anomalies	2
3.0	Relationships Between Anomalies in Different Media	5
4.0	Factors Affecting Biosphere Anomalies	7
4.1	Susceptibility of the Uranium Deposit to Groundwater Leaching	7
4.2	Chemical and Physical Controls on Uranium Mobility	9
5.0	Conclusions	10
REFERENCES		11

APPENDIX A Site Descriptions

Site 1 Jabiluka Deposit, Australia
Site 2 Koongarra Deposit, Australia
Site 3 Yeelirrie Deposit, Australia
Site 4 Forstau, Austria
Site 5 Bancroft, Ontario, Canada
Site 6 Blizzard Deposit, British Columbia, Canada
Site 7 Kaipokok, Newfoundland, Canada
Site 8 Lineament Lake, Northwest Territories, Canada
Site 9 Midwest Deposit, Saskatchewan, Canada
Site 10 South March, Ontario, Canada
Site 11 Karelia, Finland
Site 12 Lower Buller Gorge, New Zealand
Site 13 Koprubasi, Turkey
Site 14 Yellow Cat, Utah, United States

LIST OF TABLES

		Page
Table 1	Summary of Available Data	1a
Table 2	Anomaly Sizes and Maximum Concentrations for Each Medium Per Study Site	2a
Table 3	Ranges of Anomaly Sizes and Maximum Concentrations	2b
Table 4	Typical Anomaly Sizes and Maximum Concentrations	5a
Table 5	Transfer Coefficients	5b

1.0 INTRODUCTION

A study of the uranium concentrations and anomalies in the biosphere was undertaken. The purpose of the study was to provide data on typical concentrations and anomaly sizes in sediments, surface waters, groundwaters, soils and plants due to the migration of uranium from a buried ore deposit. The information in this report can be used for comparison with biosphere models which predict the migration of uranium from radioactive waste buried in a vault. The data was collected from a literature search of uranium exploration studies. The report provides details on the differences between uranium concentrations and anomalies in the various media studied and on the factors affecting migration in the biosphere.

For each of the fourteen sites selected from a literature survey, information on uranium concentrations in rocks, water borne sediments, surface waters, groundwaters, soils and plants were compiled. Appendix A presents the information for each site in two sections: i) Site Description and ii) Uranium Anomaly Description. The Site Description includes general information on the setting of the area, such as climate, topography, geology, and geography, and ecology. The Uranium Anomaly Description provides all relevant uranium data including background and anomalous levels, ranges and means and the size of anomalies in each of the six biosphere compartments (rock, sediment, surface water, groundwater, soil and plants). A list of the sites and the information available for each is provided in Table 1.

Table 1 indicates that the availability of site data, in order of decreasing availability, is rocks, sediments, groundwater, surface water, soils and plants.

The threshold used in defining an anomaly and consequently the size of the anomaly were found to be dependent on the scale of the study or on the sample density. For example, at the Bancroft site, a surface water survey of a 4500 km^2 area with a sampling density of 1 sample per 3.3 km^2, defined a 3500 km^2 anomaly for a threshold of 10 ppb and defined a 30 km^2 anomaly based on a value of greater than 60 ppb. Results of surface waters collected from a smaller area of 144 km^2 indicated that the sizes of anomalies are probably significantly smaller with a typical anomaly size of 1 km^2. Drainage through mine tailings in the Bancroft area also suggested that surface water anomalies are on the scale of 1 km^2 or less. For studies that did not provide a threshold value for anomalous concentrations, estimates of anomalies were based on levels twice that of background or of mean concentration depending on what information was available.

TABLE 1 SUMMARY OF AVAILABLE DATA

SITE	ROCK	SED	S W	G W	SOIL	PLANT
1 Jabiluka, Australia	**			**		
2 Koongarra, Australia	**	*		**	*	
3 Yeelirrie, Australia	**			*	*	
4 Forstau, Austria	*	**	**		**	
5 Bancroft, Ont, Canada	**	*	**	*	*	*
6 Blizzard, B.C., Canada	**	*	*	*	*	*
7 Kaipokok, Nfld., Canada	*	*	*			
8 Lineament Lake, NWT, Can	*	**	*			
9 Midwest, Sask., Canada	**	**	**		**	*
10 South March, Ont, Canada	*	*	*	*	**	**
11 Karelia, Finland	*	**			*	
12 Lower Buller Gorge, New Zealand	*	**	**		*	**
13 Koprubasi, Turkey	*	**		**		
a) Killik	*				**	
b) Ecinlitas	*			**		
14 Yellow Cat, Utah, USA	*			*	**	**

* Some data ** Good data

2.0 Description of the Biosphere Anomalies

A summary table of the size of the anomalies and the maximum concentration measured for each medium at each site is provided in Table 2. Maximum concentrations were used as indication of the degree of accumulation in a media. It is recognized that this method can lead to misinterpretation, however, it was used here because it is a clear and concise way to summarize data in a table format. For each site, there may have been studies completed at different scales. As discussed above, these differences in scale can generate different sizes of anomalies and sometimes different maximum concentrations. In order to differentiate between these studies, for each site the data from regional studies are shown in bold in Table 2 if data from a more local study is also available. The anomaly size represents the typical value inferred for that particular medium and site, and is not based on statistical analysis. For additional information on the number of anomalies and their range in size refer to Appendix A.

The usefulness of the data in delineating the areal extent of anomalies, in order of decreasing usefulness, is rocks, sediments, soils, surface water and groundwater and lastly plants. This list is not the same as the one based on the availability of data and this indicates that although there may be uranium data for a specific medium there may not be sufficient information to outline an anomaly. The absence of anomalies for sites with sufficient data is indicated in Table 2 as 0 km^2. For some stream water and sediment data it was possible to outline anomalies based on the length within the drainage system rather than area. This was also the case for some soil surveys where the samples were collected from transects rather than grids.

Table 3 presents the ranges of anomaly size and ranges of maximum concentration for each medium, as well as the site from which each value is taken. In some cases, assumptions were made in order to determine the size of the anomaly. All such assumptions are explained in the Uranium Anomaly Descriptions in Appendix A.

The results of this study show that the sediments and surface water environments have the largest uranium dispersion. It is noted that the maximum value for both of these media are from regional studies (4600 km^2 for the sediment study at Site 8 - Lineament Lake, and 4500 km^2 for the surface water study at Site 5 - Bancroft). Both these studies are based on relatively high anomalous thresholds of 15 ppm and 60 ppb, respectively.

Additional information on the anomalies in each of the media is discussed below.

Table 2: Anomaly Sizes and Maximum Concentrations for Each Medium per Study Site

Country	Site	SIZE								[U] max					
		Rock km^2	Surface water km^2	Surface water km	Groundwater km^2	Sediment km^2	Sediment km	Soils km^2	Soils km	Plants ash km^2	Rock ppm	Surface water ppb	Groundwater ppb	Sediment ppm	Soils ppm	Plants ppm ash
Australia	Jabiluka	0.07			0						4500		28			
		0.50														
Australia	Koongarra	0.01			0		0		0.2		82000		4100	60	5000	
		0.004									11000					
Australia	Yeelirrie	0							0.5		1300		400		700	
Austria	Forstau					0.5		1.50E-05				5		15	4.8	
Canada	Bancroft, Ont.		30					4			2000	760			8	50
				1.0			3.2				2000	2.7		33	500	50
				1.2			8.0				2000	2.7		33	500	50
Canada	Blizzard, BC	0.16	0.10		0.2	0		0.1		0.1	30000	1.7	85	21.6	360	420
												1.7	85			2100
Canada	Kaipokok, Nfld.					3.5					5400	2				
			3								5400			104		
			13								5400			104		
Canada	Lineament Lake, NWT		16			230					5	1.8		70		
Canada	Midwest, Sask.	0.05	0.50			2		0.2			430000	3		13.2	38	1
Canada	South March, Ont.	0.09						0.25			424		73	11	110	0.18
Finland	Karelia						3.5							2265	202	
New Zealand	Lower Butler Gorge	1	1			1				1	150000	2.76		620	63850	21500
												2.76		620		86
Turkey	Koprubasi				6.25	0.5					5000		282	34		
					0.5						5000		50			
								0.85			5000				10	
United States	Yellow Cat, Utah	0.01							0.1	0.45	22300		600		61	22

TABLE 3 RANGES OF ANOMALY SIZES AND MAXIMUM CONCENTRATIONS

	RANGE OF ANOMALY SIZE	RANGE OF MAX VALUES
ROCKS	0.0007 km^2 (site 14) - 9 km^2 (site 3)	5.3 ppm (site 8) - 150,000 ppm (site 12)
SEDIMENTS	0.5 km^2 (site 4 & 13) - 230 km^2 (site 8) 3.5 km (site 11) - 8 km (site 5)	11 ppm (site 10) - 2285 ppm (site 11)
SURFACE WATERS	0.1 km^2 (site 6) - 30 km^2 (site 5) 1.2 km (site 5)	1.7 ppb (site 6) - 700 ppb (site 5)
GROUNDWATERS	0.2 km^2 (site 6) - 0.5 km^2 (site 13)	28 ppb (site 1) - 4100 ppb (site 2)
SOILS	0.000015 km^2 (site 4) - 4 km^2 (site 5) 0.1 km (site 14) - 0.5 km (site 3)	4.8 ppm (site 4) - 63,850 ppm (site 12)
PLANTS	0.1 km^2 (site 6) - 1.0 km^2 (site 12)	0.18 ppb (site 10) - 21,500 ppb (site 12)

Rock Anomalies:

Yeelirrie is the only site with a uranium rock anomaly greater than 1 km^2. Yeelirrie is a chemical deposit formed in regolith material and therefore is more suspectible to dispersion. Information was not obtained for the size of the ore deposits for Forstau, Koprubasi, Kaipokok and Karelia. For Bancroft, because of the large number of ore deposits in the area, no data were included for the size of the rock anomalies. Lineament Lake is the only site where no mineralization has been discovered, and South March has only low levels of mineralization. All sites except these two have maximum uranium concentrations greater than or equal to 1300 ppm.

Sediment Anomalies:

Sediment anomalies were outlined for 8 of the sites (6 with areal data: Forstau, Kaipokok, Lineament Lake, Midwest, and Lower Buller Gorge; and 2 with linear data: Bancroft and Karelia). The size of the anomalies for the 6 sites with areal data is less than or equal to 3.5 km^2, except for Lineament Lake with an anomaly of 230 km^2. The linear anomalies are 3.2 and 8 km for Bancroft and 3.5 km for Karelia. The majority of these sites have uranium concentrations between 10 to 105 ppm. Higher values were measured at Karelia and Lower Buller Gorge, at 620 and 2285 ppm, respectively.

Surface Water Anomalies:

Only 6 sites had areal data on anomalous uranium concentrations in surface water (Bancroft, Blizzard, Kaipokok, Lineament Lake, Midwest and Lower Buller Gorge). Linear data was also available for Bancroft. The areas ranged from 0.1 to 30 km^2. Two linear values were determined to be 1 and 1.2 km. Surface water concentrations are all less than 5 ppb with the exception of Bancroft with values as high as 700 ppb. There is a good possibility that this high value indicates contamination from mining activities. The surface water anomaly at the Blizzard site was unexpectedly small with low concentrations (0.1 km^2 and 1.7 ppb) as the orebody is above the water table and should be subject to oxidative weathering.

Groundwater Anomalies:

Athough groundwater concentrations are available for 7 sites, the areal extent of anomalous uranium concentrations in groundwater are available for only 2 sites, Blizzard and Koprubasi. A value of 0.2 km^2 for Blizzard is only an estimate. For the Koprubasi study a value of 0.5 km^2 was determined from a local study and a value of 0.25 km^2 was measured from a regional study. There does not seem to be a "typical" groundwater concentration for the 7 sites reporting data, as the maximum uranium concentrations range from 28 to 4100 ppb. Four of the sites had maximum uranium concentrations greater than 290 ppb.

Soil Anomalies:

Information on the areal extent of uranium concentration in soils is available for 6 sites (Forstau, Bancroft, Blizzard, Midwest, South March and Koprubasi) and on the linear extent (from transects) for 3 sites (Koongarra, Yeelirrie, and Yellow Cat). The size of the soil anomalies is typically less than 1 km^2 with the exception of Bancroft, with a value of 4 km^2. The linear anomalies are 0.5 km or less. There is a wide range in the soil concentrations (4.8 to 63850 ppm) with no "typical" value.

Plant Anomalies:

Only 3 values are available for the areal extent of anomalous uranium concentrations in plants and these are 1 km^2 or less. There is a wide range in the magnitude of the maximum plant concentrations (0.18 to 21500 ppm ash) with no "typical" value.

3.0 Relationships Between Anomalies in Different Media

Based on the above description of each anomaly it is possible to refine Table 3 to provide in some cases, more typical values for the size of anomaly and the maximum concentrations. The data provided in Table 4 is useful for assigning anticipated uranium dispersion in the biosphere. It is important to note the values in Table 4 are not based on statistics but rather on observed trends in the data. Comments are included in Table 4 as additional considerations to the typical anomaly size or maximum concentration provided.

The size of typical anomalies in Table 4 indicates that uranium is more dispersed in sediments and surface water than other media. Based on these typical values, however, the size of these anomalies is greatly reduced. Starting with a typical uranium source of 1 km^2 in the rock, anomalies of similar size as the source are expected in soils and plants, anomalies twice as large as the source are expected in sediments and surface waters and anomalies smaller than the source are possible for groundwater.

The typical size of uranium anomaly in groundwater may not be truly representative for several reasons. Because of the higher cost of monitoring groundwater, fewer comprehensive studies were carried out on this medium than for sediments and surface waters. Anomalies are more difficult to delineate in groundwater than other environments because of the importance of physical and chemical constraints on uranium migration. The difficulties and high costs of quantifying these constraints make detailed groundwater studies unattractive as a mineral exploration tool.

As part of the assessment of uranium migration in different media at different study locations, transfer coefficients can be used. Transfer coefficients are the ratios of uranium anomalies or concentrations in two media and they can provide an indication of the dispersion of uranium from one medium to another. For example, the ability of plants to accumulate uranium is often based on the plant:soil transfer coefficient (or the ratio of the uranium concentration in plants versus the uranium concentration in soils). The usefulness of transfer coefficients is determined by the representativeness of the values in the ratio. Transfer coefficients greater than 1, indicate that uranium dispersion is greater in the receiving media than in the source.

Based on the data of Table 2, transfer coefficients were calculated for the anomaly sizes and the maximum concentrations of the ratios for groundwater/rock, sediment/rock, soil/groundwater, plant/groundwater, plant/surface water, and plant/soil. The results presented in Table 5, have values between 0.1 to 6.7 for the transfer coefficients for anomaly sizes. The maximum concentration ratios have a much wider range of 6.2E-06 (in

TABLE 4 TYPICAL ANOMALY SIZES AND MAXIMUM CONCENTRATIONS

MEDIUM	SIZE	Comments	CONC	Comments
Rocks	1 km^2	exception 9 km^2 Yeelirrie	1300 ppm	exc Lineament L. 5.8 ppm South March 424 ppm
Sediment	2 km^2	exception 230 km^2 Lineament Lake	10 - 100 ppm	exc Finland 2285 ppm, New Zealand 620 ppm
Surface Waters	2 km^2	few data	5 ppb	exc. Bancroft 700 ppb, sample could be contaminated
Ground-waters	0.2 km^2	few data		no typical values (>290 ppb ??)
Soils	1 km^2 0.5 km	similiar values		no typical values
Plants	1 km^2	few data		no typical values

Table 5 Transfer Coefficients

Country	Site	Size Ratios						[U] max Ratios							
		GW/Rock	Sed/SW	Soil/GW	Plant/GW	Plant/SW	Plant/Soil	GW/Rock	SW/GW	Sed/GW	Sed/SW	Soil/GW	Plant/GW	Plant/SW	Plant/Soil
Australia	Jabiluka							6.2E-06							
Australia	Koongarra							5.0E-05		15		1220			
Australia	Yeelirrie							3.1E-04				1750			
Austria	Forstau										3000				
Canada	Bancroft, Ont.													71	6.3
			3.2								12222				0.1
			6.7								12222				
Canada	Blizzard, BC	1.3		0.5	0.5	1	1	2.8E-06	0.02	254	12706	4588	4941	247059	1.1
													24706	1235294	
Canada	Kaipokok, Nfld.														
Canada	Lineament Lake, NWT		0.10												
Canada	Midwest, Sask.		0.3								4.4E-03			367	2.9E-02
Canada	South March, Ont.							1.7E-04		151		1507	2.5		1.6E-03
Finland	Karelia														
New Zealand	Lower Buller Gorge		1.0			1					224638			7789855	0.34
											224638			31159	
Turkey	Koprubasi							5.8E-05		116					
								1.0E-05							
United States	Yellow Cat, Utah							3.6E-05				76	28		0.36

groundwater/rock) to 7.8E+06 (in plants/surface water). The concentration transfer coefficients are generally greater than 1 for the sediment/groundwater, sediment/surface water, soil/groundwater, and plant/groundwater. The plant/surface water concentration ratios vary from 1.6E-03 to 6.3.

The maximum concentration transfer coefficients of this study can be compared with the few available literature values provided in Letourneau (1987) and Sheppard (1980). The sediment/groundwater ratios are similar to the range of distribution coefficient (Kd) values reported in Sheppard (1980); listed Kd range of 7 to 139 ml/g. The groundwater/rock ratios are significantly less than these Kd values (i.e up to 1E-06 times less). The calculated sediment/groundwater ratios are generally greater than the literature Kd values by up to 1E+03 times. Sediment/surface waters ratios are within the range provided by Letourneau (1987) who reported values of 7.5 to 885,000. The plant/soil ratios of the study sites are within the range of the literature transfer coefficients (i.e. 0.0001 to 8 reported in literature).

4.0 Factors Affecting Biosphere Anomalies

Many factors affect the migration of uranium in the biosphere. Two of the more important factors are: 1) susceptibilty of the uranium deposit to leaching; 2) physical and chemical controls on uranium migration. These factors are discussed below.

4.1 Susceptibility of the Uranium Deposit to Groundwater Leaching

One of the most important factors affecting biosphere anomalies is the susceptibility of the uranium in the rock to leaching by groundwater. In order to compare the effect of this parameter on the biosphere anomalies at the study areas, the sites were grouped into various categories. These categories are 1) type/host rock of uranium deposit, and 2) hydrogeologic setting. The importance in classifying the type/host rock of the deposit is for an indication of the relative susceptibilty to leaching by groundwater. This characteristic together with the hydrogeologic setting are the primary controls on uranium dispersion to the biosphere.

Type/Host Rock of Uranium Deposit

The following discussion on the effect of the type/host rock of the uranium deposit on uranium migration into groundwater is a general discussion of only basic concepts and ignores the many complicating factors. In general terms, sedimentary rocks can be considered the rock type most susceptible to leaching by groundwater. This is because these rock types are generally the major conduits of groundwater and are therefore more exposed to leaching processes. This principle applies to sandstones and other permeable sedimentary rocks which are listed below as the most common rock type for the uranium deposits in this study. Metasedimentary rocks and other sedimentary rocks that are less permeable than sandstones but that have bedding planes serving as conduits for groundwater flow are also susceptible to leaching. Rocks with low permeabilities and that lack bedding planes are not susceptible to leaching unless they have structural feature (i.e. fractures, faults) that allow for the transport of groundwater. These rocks are generally of igneous or metamorphic origin.

The 14 sites are classified as follows based on the type/host rock of uranium deposit.

I	Hydrogenetic:		
	a) Syngenetic	Yeelirrie, Australia	Calcrete
		Kaipokok , Nfld, Can	Sedim/Extrusiv
	b) Epigenetic	Blizzard, B.C., Can	Sandst/Mudst
		Midwest, Sask., Can	Sandstone
		South March, Ont., Can	Dolomite
		Low. Buller Gorge, N.Z.	Sandstone
		Yellow Cat, Utah, USA	Sandstone
		Koprubasi, Turkey	Sandstone

I	Metamorphic	Forstau, Austria	Phyllite
		Bancroft, Ont., Canada	Marble/Pegmatite
		Jabiluka, Australia	Schist
		Karelia, Finland	Quartzites
		Koongarra, Australia	Schist
III	Igneous	Lineament L., NWT, Can	Granite/Monzonite

The host rock was considered in the selection of the study sites in consideration of underground burial of radioactive waste in Precambrian Shield bedrock. Unfortunately, the majority of studies with a comprehensive study of uranium in the biosphere were in sedimentary or metasedimentary rocks, as illustrated in the above list. The Lineament Lake study has been included, even though it does not have any known uranium deposits, because the source of uranium has been postulated to be igneous rocks in the area.

Hydrogeologic Setting

The critical factor for assessing the extent of migration in the biosphere is the dispersion mechanism. The flow of groundwater through the uranium deposit up to the near surface environment is the mechanism of most interest for this study. These areas with upward groundwater flow are called discharge zones and these zones can serve as analogies to migration from the deep burial of radioactive waste.

Of the 14 sites selected, Jabiluka, Koongarra, Yeelirrie, Forstau, Blizzard, South March, and Karelia appear to be in discharge zones. For Jabiluka and Koongarra, no groundwater anomalies were outlined. In the case of Jabiluka no high concentrations were measured in the groundwater but for Koongarrra, high levels were measured but only within the orebody. This was also the case for Blizzard although the uranium levels were almost 50 times less than at Koongarra. The Blizzard groundwater anomaly (0.2 km^2) has been delineated to be approximately slightly larger than the orebody. The study at Koongarra stressed the important controls that pH and Eh have on uranium migration in the groundwater in particular.

South March is located in a discharge zone, however there is only regional information on the concentrations in groundwater. A very rough estimate of the size of the groundwater anomaly, not included in Table 2, is 0.2 km^2.

The Forstau and Karelia sites did not have groundwater studies but both areas have hydrodynamic dispersion within the overburden/soil based on small scale studies. The Forstau, Austria study area was 200 km^2. Pitchblende mineralization is found in sericite-quartz phyllite. The ore lenses vary in length from 10 to 100 m. The ore zone, based on surface radioactivity has been traced for several kilometres on both the east and west sides of Forstau valley. No secondary mineralization has been observed on the ground surface or

below. No information on the uranium concentrations in this deposit was provided. A detailed soil survey was carried out over a mineralized zone. This area had a steep slope of 30 degrees and soil thicknesses of up to 2 m. Although there are anomalous results (i.e. greater than 3.0 ppm) the authors suggest that the results are not indicative of mineralization. The anomalous soil concentrations are reported to be due to hydromorphic dispersion in a fractured rock groundwater zone as they occur along streams in which numerous springs and streams are present. A typical size for the soil anomaly at this site is 15 m^2 (1.5 E-5 km^2).

At the time of the Karelia study, no uranium ore of economic grade was known in Finland although several mineralized zones had been located. Mineralization is in Karelian metasediments as small uraninite and pitchblende occurrences found mainly in quartzite. Uranium also occurs in metadiabase contacts and in small pitchblende veinlets within the metadiabases. Drift samples from the Paukkajanvaara area (Lake Paukkajajarvi) have anomalous uranium concentrations in an area of bedrock mineralization but not in a mineralized boulder fan. The highest uranium values in the drift are close to the mineralized bedrock and the contents decrease rapidly upward. The author concludes from these results that the anomaly is hydromorphic in origin. Unfortunately, the sampling density did not allow for delineating the size of the anomaly.

4.2 Chemical and Physical Controls on Uranium Mobility

Physical and chemical conditions in all media control whether or not uranium is mobile. These controls are extremely complicated and were not directly addressed in this study. This is because many of the papers reviewed did not address these factors or the complexity of the controls was too detailed to incorporate into this study. However, because of their importance in biosphere modelling of uranium migration, a listing is provided of some of the important factors affecting the size and concentration of uranium biosphere anomalies.

Chemical Properties:

Important chemical properties controlling uranium dispersion in the biosphere are those factors affecting adsorption, precipitation, and coprecipitation (i.e. pH, pE, hydroxides, oxyhydroxides, oxides, clay minerals, organic matter, and complexing anions).

Physical Properties

Physical properties important in controlling the extent of uranium dispersion in the biosphere are sediment and soil texture (grain size and surface area) and plant characteristics (i.e. plant type, plant organ, plant age, and root distribution) and seasonality.

5.0 Conclusions

A literature review of uranium exploration studies has provided information on the size and concentrations of uranium anomalies in the biosphere. The scale and sampling density of the study affect the anomalous threshold and the size of the anomaly. Statistical analyses of the data on anomaly sizes are not possible because of the lack of information as well as the variations between studies in terms of scale and threshold values used.

Uranium is most widely dispersed in sediments and surface waters. The fact that the data suggest that uranium is less dispersed in groundwater may be a function of the lack of adequate data. Based on assigning typical values to the size of anomalies in each media, it is possible to compare the dispersion of uranium in the different environments. A typical value of 1 km^2 for the source in rocks generates similar sized anomalies in both soils and plants, predicts anomalies twice that size in sediments and surface waters and has smaller anomalies for groundwater. The small size of the typical anomalies in groundwater may be a function of the generally large sampling density used for this medium.

REFERENCES

Beaven, A.P. 1958. The Labrador uranium area. In: Proceedings of the GAC, December, 1958, pp. 137-145.

Beck, A.C., Reed, J.J., Willett, R.W. 1958. Uranium mineralization in the Hawks Craig Breccia of the Lower Buller Gorge Region, South Island, New Zealand. New Zealand Journal of Geology and Geophysics 1: 432-450.

Boyle, D.R. 1982. The Formation of Basal-Type Uranium Deposits in South Central British Columbia. Economic Geology 77: 1176 -1200.

Bjorklund, A.J., Tenhola, M., Rosenberg, R. 1976. Regional Geochemical Uranium Prospecting In Finland. In: Proceedings on Exploration of Uranium Ore Deposits, Vienna, 1976, IAEA, pp. 283-29.

Bjorklund, A.J. 1976. Use of Till in Geochemical Uranium Exploration. In: Proceedings on Exploration of Uranium Ore Deposits, Vienna, 1976, IAEA, pp. 297-309.

Butt, C.R.M. 1988. Major uranium provinces: Yilgarn Block and Gascoyne Province, Western Australia. In: Recognition of Uranium Provinces, Proceedings of a Technical Meeting, London 18-20, September, 1985, IAEA, pp. 273-304.

Cameron, E.M., Durham, C.C. 1974. Geochemical studies in the Eastern part of the Slave Structural Province. GSC Paper 74-27, 22 pg.

Cameron, E. Mazzucchelli, R.H., Robbins, T.W. 1980. Yeelirrie calcrete deposit, Murchison Region, Western Australia. Journal of Exploration Geochemistry, 12: 350-353.

Cannon, H.L. 1964. Geochemistry of rocks and related soils and vegetation in the Yellow Cat Area Grand County, Utah. USGS Bulletin 1176 127 pg.

Card, J.W. 1978. Spontaneous deposition of radon products from air. M.Sc. thesis, Carleton University, Ottawa, 108 pg.

Chamberlain, J.A. 1964. Hydrogeochemistry of uranium in the Bancroft-Haliburton Region, Ontario. Geological Survery of Canada Bulletin 119, 19 pg.

Charbonneau, R.W. Jonasson, Ford, K.L. 1975. Cu-U mineralization in the March Formation Paleozoic rocks of the Ottawa-St. Lawrence Lowlands. GSC Paper 75-1, Part A, pp.229-233.

Cohen, N.E., Brooks, R.R., Reevers, R.D. 1969. Pathfinders in geochemical prospecting for uranium in New Zealand. Economic Geology 64: 519-525.

Darnely, A.G., Grasty, R.L. 1971. Mapping from the air by gamma-ray spectrometry. CIM Special Vol. 11: 485-500.

Deutscher, R.L., Mann, A.W., Giblin, A. 1980. Ground water in the vicinity of the Jabiluka Deposits. In: Uranium in the Pine Creek Geosyncline. Proceedings of the International Uranium Symposium, Sydney, 4-8 June 1979, IAEA, pp. 477-486.

Dunn, C.E. 1982. Detailed biogeochemistry studies for uranium in NEA/IAEA Athabasca test area. In: Uranium exploration in Athabasca Basin, GSC Paper 82-11, Ed. E.M. Camerson, pp. 259-271.

Dyck, W. 1980. Uranium, radon, helium and other trace elements and gases in well waters of parts of the St. Lawrence Lowlands, (Ottawa Region) Canada. Journal of Geochemical Exploration 13: 27-39.

Dyck, W. 1982. Geochemical studies of lakes near Midwest and McClean uranium deposits. In: Uranium exploration in Athabasca Basin, GSC Paper 82-11, Ed. E.M. Cameron, pp. 243-257.

Dyck, W., Camerson, E.M. 1975. Surface lake water uranium-radon survey of the Lineament Lake area, District of Mackenzie. GSC Paper 75-1A pp. 209-212.

Dyck, W., Camerson, E.M., Richardson, K.A. 1982. Radon, gamma-ray spectrometer, and trace element investigations of soils at Midwest and McClean uranium deposits. In: Uranium exploration in Athabasca Basin, GSC Paper 82-11, Ed. E.M. Cameron, pp. 215-241.

Environcon Ltd. 1980. Blizzard Uranium Property Baseline Environmental Studies. Volumes 1 - 4.

Ford, K.L. 1975. Petrography, geochemistry and geophysics of a uranium-copper occurrence, South March, Ontario, B.Sc. thesis, Carleton Univversity, Ottawa, 62 pg.

Foy, M.F., Gingrich, J.E. 1977. A stream sediment orientation programme for uranium in the Alligator River Province, Northern Territory, Australia. Journal of Exploration Geochemistry, 8: 357-364.

Giblin, A.M., Snelling, A.A. 1983. Application of hydrogeochemistry to uranium exploration in the Pine Creek Geosyncline, Northern Territory, Australia. Journal of Geochemical Exploration, 19: 33-55.

Gordon, S.L. 1986. The environmental geochemistry of total uranium and ^{226}Ra at the South March uranium occurrence, Ontario, M.Sc. thesis, Carleton University, Ottawa, 131 pg.

Grasty, R.L., Charbonneau, B.W., Steacy, H.R. 1973. A uranium occurrence in Paleozoic rocks west of Ottawa. GSC Paper 73-1A, pp.

286-289.

Hegge, M.R., Mosher, D.V. Eupene, G.S. 1980. Geologic Setting of the East Alligator Uranium Deposits and Prospects. In: Uranium in the Pine Creek Geosyncline. Proceedings of the International Uranium Symposium, Sydney, 4-8 June 1979, IAEA, pp. 259-272.

Jonasson, I.R., Dyck, W. 1974. Some studies of geochemical dispersion about a small uranium showing, March Township, Ontario. GSC Paper 74-1B, pp. 61-63.

Letourneau, C. 1987. Transfer of radionuclides of the uranium and thorium decay chains in aquatic and terrestrial environments. Atomic Energy Control Board Information Report 0237-E.

King, J., Tauchid, M., Frey, D. et al. 1976. Exploration for Uranium in Southwestern Anatolia. In: Proceedings on Exploration of Uranium Ore Deposits, Vienna, 1976, IAEA, pp. 501 - 529.

Meyer, W.T. 1969. Uranium in lake water from the Kaipokok Region, Labrador. Quarterly of the Colorado School of Mines 64(1): 377-394.

Minatidis, D.G., Slatt, R.M. 1976. Uranium and copper exploration by nearshore lake sediment geochemistry, Kaipokok region of Labrador. Journal of Geochemical Exploration 5: 135-144.

Morse, R.H. 1971. Comparison of geochemical prospecting methods using radium with those of radon and uranium. CIM Special Vol. 11: 215-230.

Needham, R.S., Stuart-Smith, P.G. 1980. Geology of the Alligator Uranium Field. In: Uranium in the Pine Creek Geosyncline. Proceedings of the International Uranium Symposium, Sydney, 4-8 June 1979, IAEA, pp. 233-256.

Robertson, J.A. 1981. The uranium deposits of Ontario - Their distribution and classsification. OGS Miscellaneous Paper 86, 37. pg.

Sheppard, M.I. 1980. The environmental behaviour of uranium and thorium. Atomic Energy of Canada Limited Report AECL-6795.

Sheppard, M.I., Olchowy, L., Mayoh, K.R. 1981. Uranium, thorium, radium, and arsenic concentrations of plants and soils of the Precambrian Shield: A preliminary study. AECL TR-159, 32 pg.

Simpson, M.A. Sopuck, V.J. 1982. Till geochemistry near the Midwest uranium deposit. In: Uranium exploration in Athabasca Basin, GSC Paper 82-11, Ed. E.M. Cameron, pp. 207-214.

Smith, A.Y., Camerson, J., Barretto, P.M.C. 1976. Uranium Prospecting In Austria. In: Proceedings on Exploration of Uranium Ore Deposits, Proceedings of a symposium, Vienna, 29 March - 2

April, 1976, IAEA, pp. 657-670.

Snelling, A.A. 1984. A soil geochemistry orientation survey for uranium at Koongarra, Northern Territory. Journal of Geochemical Exploration, 22: 83-99.

Snelling, A.A. 1989. Koongarra Uranium Deposits. In: Alligator Rivers Analogue Project, Progress Report, March - May 1990, Australian Nuclear Science and Technology Organization, pp. 49-66.

Sopuck, V.J., de Carle, A., Wray, E.M. 1983. Application of lithogeochemistry to the search for unconformity-type uranium deposits in the Athabasca Basin. In: Uranium exploration in Athabasca Basin, GSC Paper 82-11, Ed. E.M. Cameron, pp. 191-205.

Whitehead, N.E., Brooks, R.R. 1969a. Aquatic bryophytes as indicators of uranium mineralization. The Bryologist 72: 501-507.

Whitehead, N.E., Brooks, R.R. 1969b. Radioecological observations on plants of the Lower Buller Gorge Region of New Zealand and their significance for biogeochemical prospecting. Journal of Applied Ecology 6: 301-310.

Wodzicki, A. 1959. Geochemical prospecting for uranium in the Lower Buller Gorge, New Zealand. New Zealand Journal of Geology and Geophysics 2: 602-612.

APPENDIX A

Site Descriptions

SITE 1
JABILUKA DEPOSIT, AUSTRALIA

This site has been included because of interesting groundwater results.

References

Deutscher, R.L., Mann, A.W., Giblin, A. 1980. Ground water in the vicinity of the Jabiluka Deposits. In: Uranium in the Pine Creek Geosyncline. Proceedings of the International Uranium Symposium, Sydney, 4-8 June 1979. IAEA. pp. 477-486.

The results of sampling 17 exploration drill holes for major and minor element chemistry are provided in this study. The authors compare the results with that of the host rocks.

Hegge, M.R., Mosher, D.V. Eupene, G.S. 1980. Geologic Setting of the East Alligator Uranium Deposits and Prospects. In: Uranium in the Pine Creek Geosyncline. Proceedings of the International Uranium Symposium, Sydney, 4-8 June 1979. IAEA. pp. 259-272.

This report provides a description of Jabiluka One and Two deposits.

Needham, R.S., Stuart-Smith, P.G. 1980. Geology of the Alligator Uranium Field. In: Uranium in the Pine Creek Geosyncline. Proceedings of the International Uranium Symposium, Sydney, 4-8 June 1979. IAEA. pp. 233-256.

General geology is provided in this paper.

Site Description

The Jabiluka deposit is found in the Alligator Rivers Uranium Field in the northeast part of the Pine Creek Geosyncline (Figure 1-1).

There are two major deposits (Jabiluka One and Jabiluka Two) and they hosted by the deformed and metamorphosed lower member of the Cahill Formation. As shown in Figure 1-2, the unconformably overlying sandstone of the Kombolgie Formation has been eroded away over Jabiluka One.

Uranium Anomaly Descriptions

A summary of the uranium concentrations in the rocks, and groundwaters is presented in Table 1-1. The extent of any anomalies is provided is this table.

<u>Uranium Rock Anomalies:</u>

The host rocks are mainly chlorite and/or graphite schists and

their brecciated equivalents. Pitchblende is the primary uranium mineral. The observed part of the formation contains four separate ore-bearing horizons which have been folded and dip to the south (Figures 1-3a, 1-3b). A third deposit had been indicated from a drill hole south of Jabiluka One.

Groundwater Anomalies:

Samples were collected from exploration drill holes and from augered drill holes, mostly at levels just below the water table. The waters were reported to be mildly reducing. Levels of 3 ppb were measured in the vicinity of the ore. It was reported that the schists of the Cahill Formation were unreactive and therefore there is very little reaction with present-day groundwaters. It was concluded that either this lack of reactivity and/or the schists relative impermeability accounted for the typically low uranium levels in the groundwater and the continued existence of a large tonnage of high grade ore close to the surface.

TABLE 1-1 URANIUM CONCENTRATIONS AND ANOMALIES AT JABILUKA, AUSTRALIA

Media	Concentrations	Anomalies
ROCK: mineralization occurs in and near veins and breccia zones in schists high grade reducing ore near surface two ore bodies separated from each other by 300 m	profiles along 3 drill holes in Jabiluka One indicate 0.45 % ore grade with a thickness of approx. 20 m in places	2 deposits a) Jabiluka One: approx. 0.07 (250 x 225 m^2), from ground surface - <200m? b) Jabiluka Two: approx. 0.5 km^2 (1 x 0.5 km^2), from 20 m below g.s. - 220 m
GROUNDWATER: samples from exploration drill holes (17?), augered holes and billabongs, all samples except 3 collected just below water table study area approx. 3 km^2 (2000 x 1350 m^2)	n = 47 <d.l. (?<1 ppb) - 28ppb 44 samples <10 ppb	no anomalies

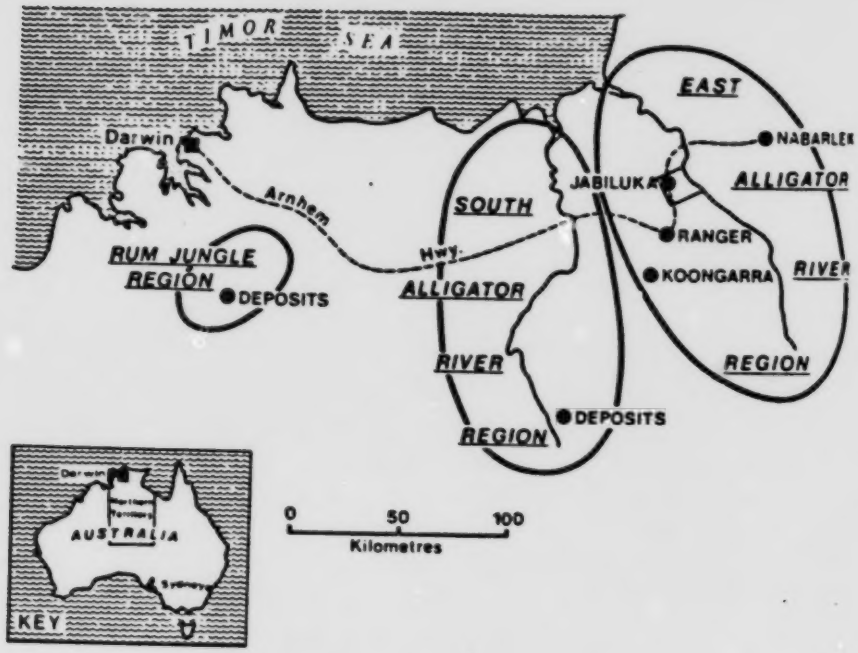


Figure 1-1 Site Location, Jabiluka, Australia

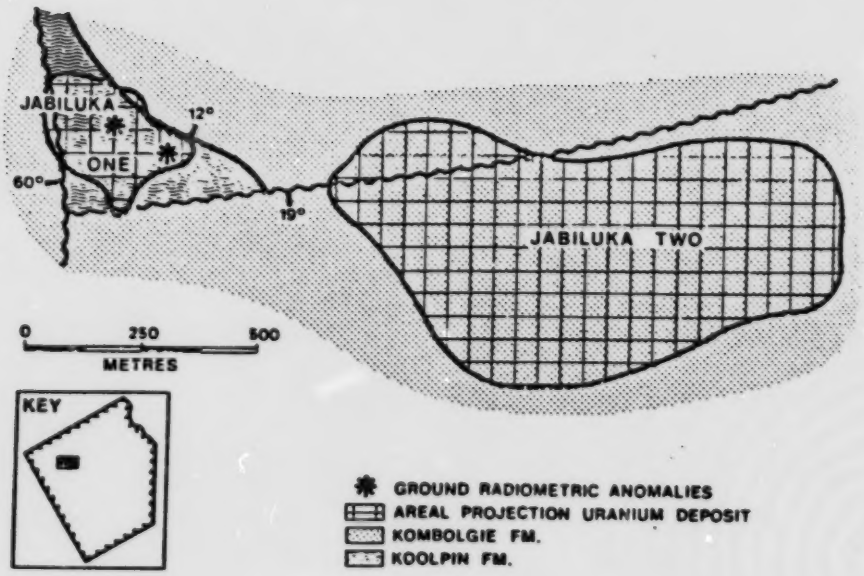


Figure 1-2 Jabiluka Orebodies

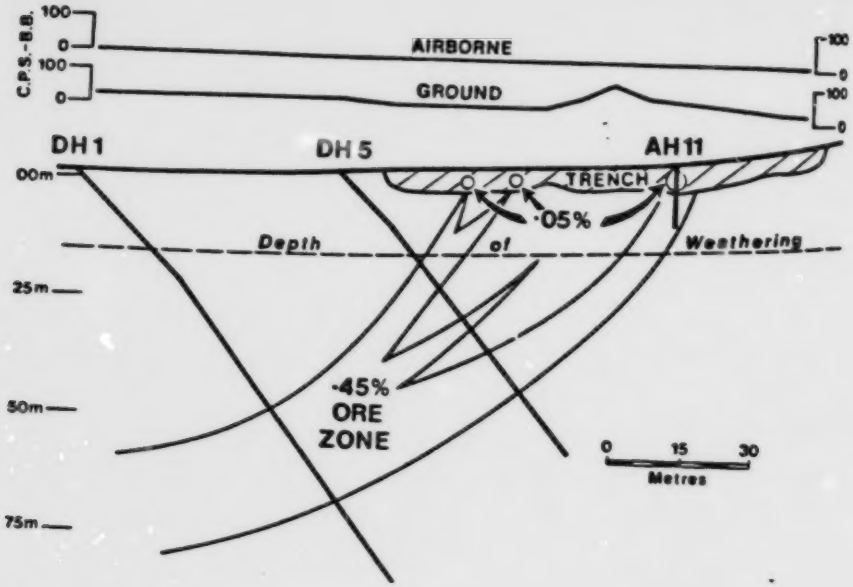


Figure 1-3a Jabiluka, Australia

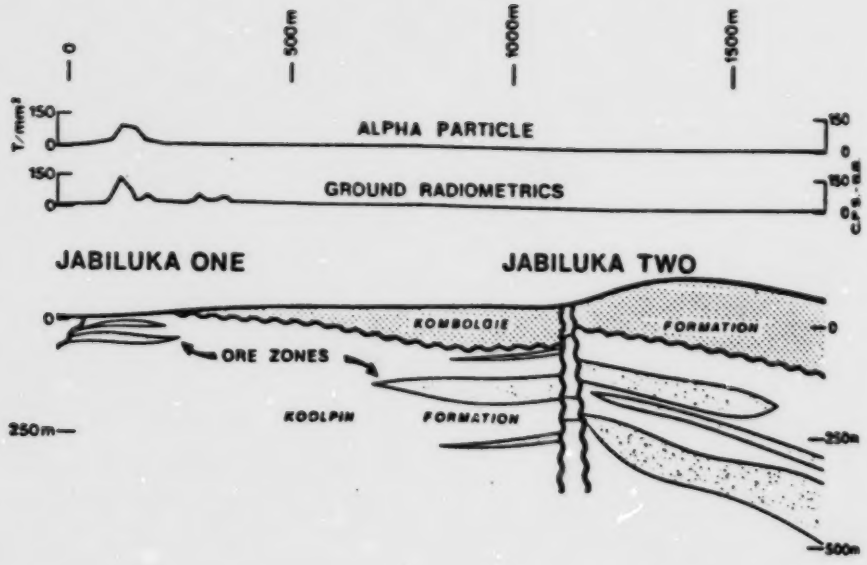


Figure 1-3b Jabiluka, Australia

SITE 2
KOONGARRA DEPOSIT, AUSTRALIA

References

Foy, M.F., Gingrich, J.E. 1977. A stream sediment orientation programme for uranium in the Alligator River Province, Northern Territory, Australia. Journal of Exploration Geology, 8: 357-364.

The paper provides the results of a stream sediment sampling from streams draining the Koongarra deposit. Results are provided for total sample and for -200 mesh samples.

Giblin, A.M., Snelling, A.A. 1983. Application of hydrogeochemistry to uranium exploration in the Pine Creek Geosyncline, Northern Territory, Australia. Journal of Geochemical Exploration, 19: 33-55.

Groundwater results for major and minor elements for samples from vertical percussion drill holes within the Koongarra Project Area are provided. The major thrust of this paper was to examine the usefulness of elements other than uranium to distinguish zones of possible mineralization.

Snelling, A.A. 1984. A soil geochemistry orientation survey for uranium at Koongarra, Northern Territory. Journal of Geochemical Exploration, 22: 83-99.

Soil samples collected from auger holes over Koongarra No. 1 were analyzed for various elemental concentrations including uranium. The purpose of the study was to determine pathfinder elements for uranium exploration.

Snelling, A.A. 1989. Koongarra Uranium Deposits. In: Alligator Rivers Analogue Project, Progress Report, March - May 1990, Australian Nuclear Science and Technology Organization, pp. 49-66.

A description of the geology of the Koongarra deposit including details on the ore is included in this reference.

Site Description

The Koongarra area is located 225 km east of Darwin and is in the Alligator Rivers Uranium Province of the Pine Creek Geosyncline (Figure 2-1). The area has hot tropical climate with pronounced wet and dry seasons. The depth to the water table is extremely variable from 8 to 9 m in the dry season to 1 m or ground surface during the wet season. The main soil types in area are lithosols and undifferentiated ironstone gravels in a sandy matrix. There is a thin layer of surficial sands overlying the residual soils.

The Koongarra uranium deposit is confined to the steeply dipping quartz-chlorite schists of the Cahill Formation which occur beneath a flat lying sandstone.

Uranium Anomaly Descriptions

A summary of the uranium concentrations in the rocks, stream sediments, ground waters and soils is presented in Table 2-1. The extent of any anomalies is provided is this table.

Uranium Rock Anomalies:

The deposit is comprised of two discrete ore bodies separated by a 100 m barren zone. Secondary mineralization (Figure 2-2) is present in ore body No. 1 in the weathered schists from below the sand cover to depths of between 25 to 30 m. The sand cover is between 1.2 to 1.5 m thick. This mineralization is from the decomposition and leaching of the primary mineralization and forms a tongue-like ore grade fan which is dispersed downslope for about 80 m to the southeast. There is no secondary mineralization for the ore body No. 2. because it occurs at depths of 50 m below ground surface whereas No. 1 occurs near ground surface beneath some talus and sand outwash. Uraninite is the primary ore mineral.

Sediment Anomalies:

Samples were collected from a 3 square kilometre area in the vicinity of the deposit (Figure 2-1). The best results were obtained from the -200 mesh. Foy and Gingrich (1977) suggest that the results outline short anomalous trains but with only 4 samples anomalous this is difficult to substantiate. The data for uranium concentration in the stream sediments is provided below and these sites correspond to the sites shown in Figure 2-1.

SITE	20	21	22	23	24	25	26	27	28	29	30
CON. (ppb)	3	10	7	15	5	4	4	6	17	3	3

SITE	31	32	33	34	35	36	37	38
CON. (ppb)	7	8	5	4	5	20	60	3

Groundwater Anomalies:

It was reported that the groundwater results are not useful for outlining ore bodies because of the influence of solubility effects of pH and Eh. Therefore no anomalies outlined, refer to Table 2-1.

Soil Anomalies:

The results of the soil sampling from a traverse over ore body No. 1 is shown in Figure 2-3. A near surface expression of the orebody is observed. As well, within the surface soils, the uranium is dispersed downgradient from the most intensely anomalous points on the traverse. The dispersion is actually better expressed with the lead data. The dispersion was interpreted to be hydromorphic in origin and due to water table upward fluctuation and lateral movement of groundwater towards Koongarra Creek.

TABLE 2-1 URANIUM CONCENTRATIONS AND ANOMALIES AT KOONGARRA, AUSTRALIA

Media	Concentrations	Anomalies
ROCK: mineralization in steeply dipping quartz-chlorite schists, western boundary of mineralization rest on a reverse fault breccia, 2 distinct orebodies separated by 100 m barren zone	No. 1 (example) Hole / Depth m / Concent. ug/g DDH1 4.7 2,271 20 82,300 29.3 30 36 214 DDH2 3 555 13 935 18 864 34 82,500 64 35,700 No. 2 results not readily available, 1 value 11,532 ug/g for both areas ore grade is >0.02 %	No. 1: secondary weathering from gr. surface to 30m, width of approx. 80m (ore grade); primary ore stike width of 450 m, true width of 30 m at the base of weathering and tapers out at about 100 m below gr. surface No. 2: strike length of 100m, occurs 50 m below gr. surface (no second. mineral.) down to at least 250 m, lower in grade than No. 1 but present over wider widths

Media	Concentrations	Anomalies
STREAM SEDIMENTS: study area 3.3 km^2 (3.3 x 1 km^2)	n = 19 for total sample: arith. mean 2.2 range = 0.4 - 18 ppm for - 200 mesh: arith. mean 10 ppm range = 3 - 60 ppm	for total sample: not useful for outlining anomalies. for - 200 mesh: b.g approx. 3 ppm if anomalous values are 15 ppm, 4 samples are anomalous
GROUNDWATER: study area approx. 1 km^2 (2.7 x 0.4 km^2) samples from percussion drill holes, sample depths vary from 9 to 105 m	n = 48 range <0.6 - 4100ppb (range for samples within No. 1 ore body 80 - 4100 ppb)	b.g 2.5 ppb, anomalous >63 ppb, only 6 holes (drilled in No. 1 ore body) are anomalous, therefore no uranium halo for either ore body
SOILS: 2 soil traverses over No. 1 ore body (length of traverse not reported but est. 400 m) sample site every 7.5 m, 10 sampling depths from ground surface to 10.6m (if soil present to 10.6 m)	n = ? results provided as a contoured profile, contours range from 12 - 1000 ppm, 2 test hole logs within vicinty of intense anomaly range from 100 to approx. 5000 ppm	most intense soil anomaly (>1000 ppm), corresponds to position of surface projection of highest grade ore lens (>1% up to 25 % U), soil anomaly at least 200 m long and 6 m deep

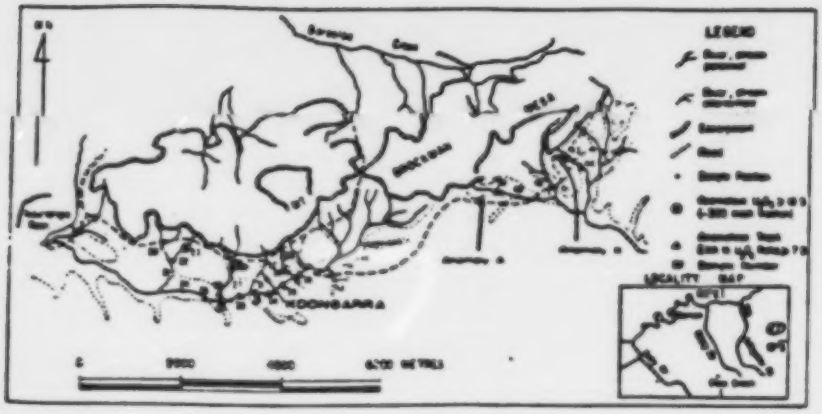


Figure 2-1 Site Location, Koongarra, Australia

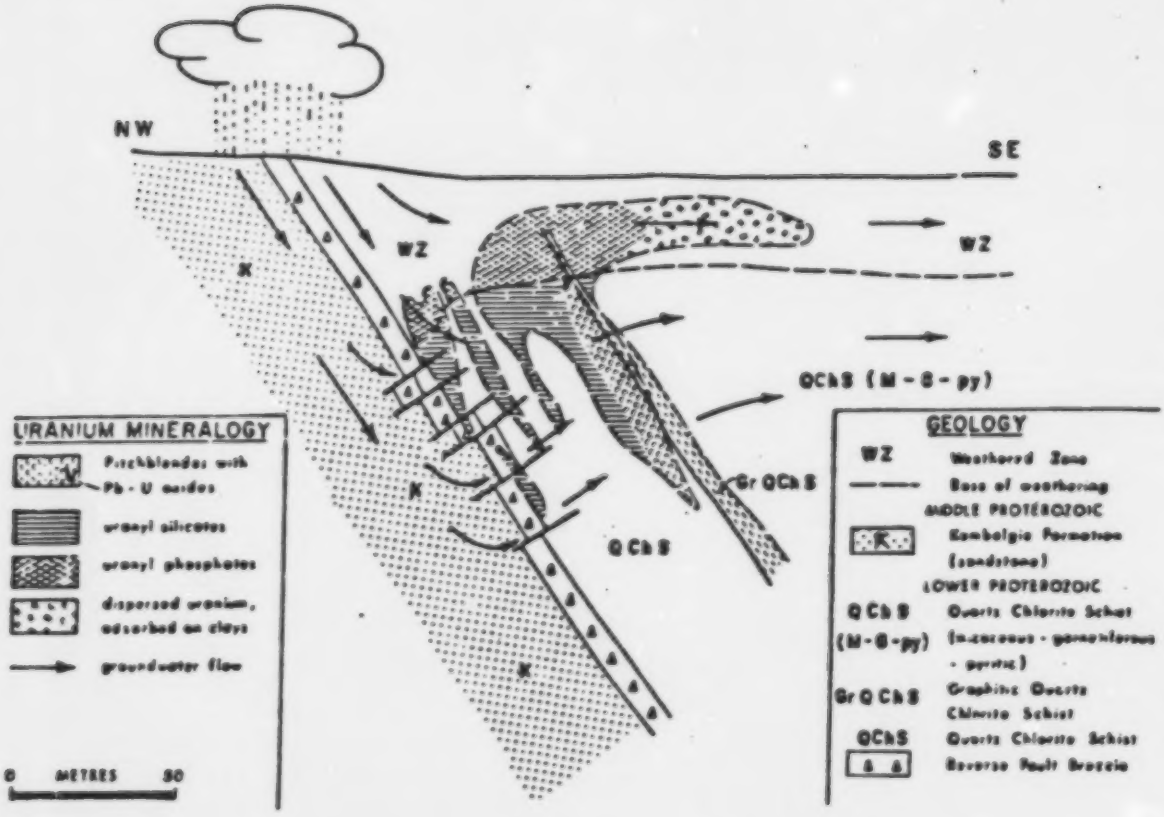


Figure 2-2 Koongarra No. 1 Orebody

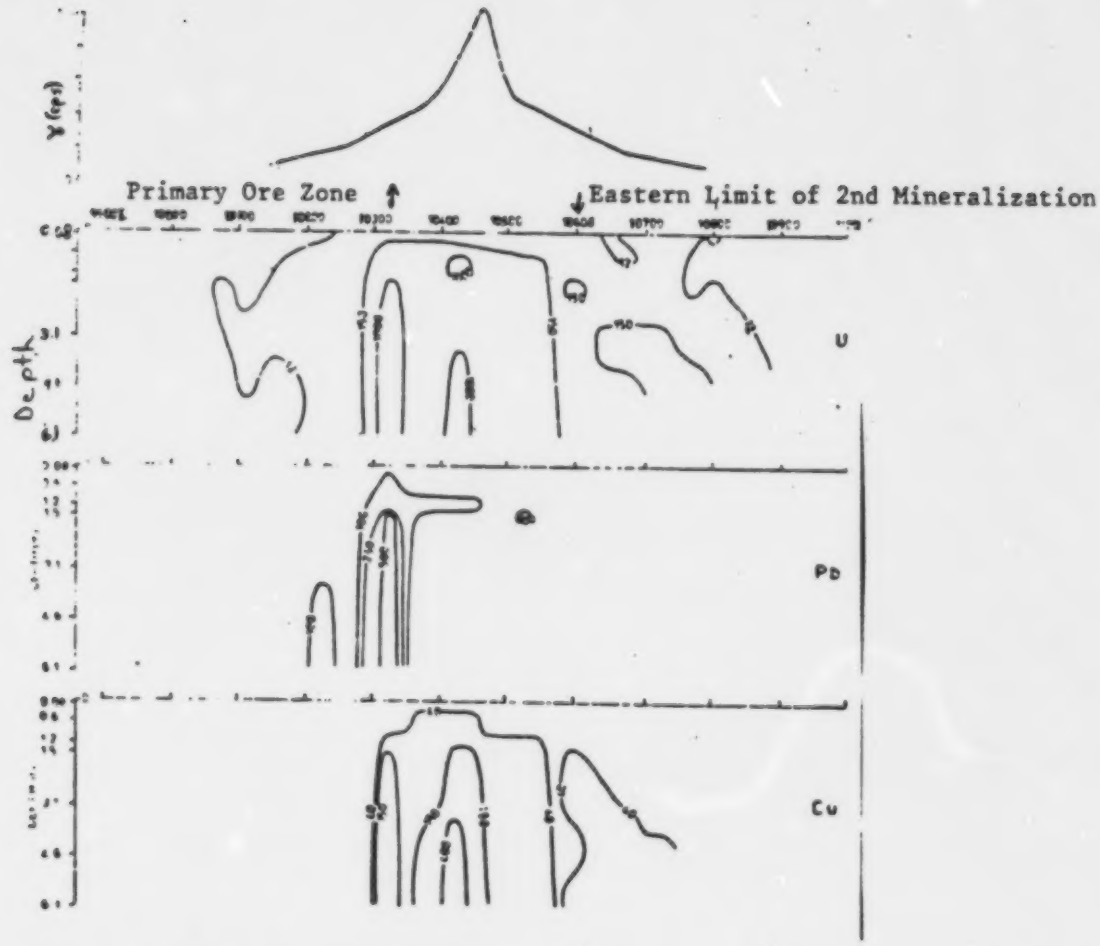


Figure 2-3 Soil Results, Koongarra, Australia

SITE 3
YEELIRRIE DEPOSIT, AUSTRALIA

References

Butt, C.R.M. 1988. Major uranium provinces: Yilgarn Block and Gascoyne Province, Western Australia. In: Recognition of Uranium Provinces, Proceedings of a Technical Meeting, London, 18-20, September, 1985, IAEA, pp. 273-304.

The regolith of the deposit is described in this reference. Results of a regional survey of groundwaters are provided.

Cameron, E. Mazzucchelli, R.H., Robbins, T.W. 1980. Yeelirrie calcrete deposit, Murchison Region, Western Australia. Journal of Exploration Geochemistry, 12: 350-353.

This paper provides a site description and results of a groundwater survey in the vicinity of the deposit and of soil sampling from a profile over the ore body.

Site Description

The Yeelirrie uranium deposit is located in southwestern Australia. It is about 70 km southeast of Wiluna. Within this area several uranium deposits have been found (Figure 3-1) of which Yeelirrie is the largest. The Yeelirrie deposit was discovered from a airborne radiometric survey at a scale of 1;250,000. The majority of the data is on uranium concentrations in the overburden and groundwater.

The orebody forms a flat-lying sheet elongated down the centre of a broad valley. The topography is very subdued because the ancient drainage system has been filled with detritus as the area become more arid. The climate is hot and arid with yearly precipitation of 200 mm and with a high evaporization rate of 2300 mm/yr. Surface water is rare and ephemeral. The regional thickness of the regolith is quite variable from near ground surface up to 100m. The available cross section data suggests that the regolith at Yeelirrie is typically 10 to 20 m thick. A cross section has been provided as Figure 3-2. The regolith is comprised of thin overburden overlying calcrete which overlies clay-quartz. The regolith rests on the Archean basement granitoid rocks.

The uranium mineralization has been deposited primarily in the calcrete and in the highly carbonated modifications of the clay-quartz of the regolith and is reported to likely be less than 1 Ma old. The nature and distribution of the mineralization is controlled by the deeply weathered semi-arid terrain and by the granitoid source rocks.

Uranium Anomaly Descriptions

A summary of the uranium concentrations in the regolith and ground waters is presented in Table 3-1. The extent of any anomalies is provided is this table.

Regolith Anomalies:

Refer to Table 3-1.

Soil Anomalies:

Refer to Table 3-1. Figure 3-2 shows the results of the soil survey from a profile over the orebody.

Groundwater Anomalies:

Results of regional and local groundwater surveys are provided in Table 3-1. Figure 3-3 illustrates the results of a local groundwater survey. Concentrations of 100 to greater than 400 ppb are present along the mineralized drainage channel. Included on Figure 3-3 are the distribution of the log of the saturation indices for carnotite which was the primary uranium mineral found in this deposit. As expected values greater than 0 are encountered in the vicinity of the ore body.

TABLE 3-1 URANIUM CONCENTRATIONS AND ANOMALIES AT YEELIRRIE, AUSTRALIA

Media	Concentrations	Anomalies
REGOLITH: this is a surficial chemical deposit, bulk of the ore lies below the water table in a transition zone from calcrete and clay-quartz horizons, oxidized deposit, carnotite is only uranium mineral	n = ? contoured profile has >500 ppm values for the ore body 35 million tons at 0.13 % U	orebody 9 x 0.75 - 1.5 km^2, extends from ground surface to depths of between 3 and 7 m, shape is lenticular, parallel to water table and ground surface
SOIL: loamy soils collected at 60 cm, 1000 m over part of ore body	n = ? profile has values from <10 - approx. 700 ppm	values decrease as move eastward away from mineralization, >10 ppm for 500 m
GROUNDWATER: 1) regional survey, study area 65,000 km^2, centered on Yeelirrie	n = 575 basemap has contoured values from <5 - >81' ppb	over Yeelirrie, anomaly >81 ppb with area 960 (48 x 20 km^2), most extensive and strongest anomaly occurred in this area with concentra. of 100 to over 450 ppb

2) orientation survey, 1350 (45 x 30 km^2) samples from pastoral boreholes	n = ? (27?) basemap has contours from <15 - >400 ppb	likely sample density too sparse to accurately delineate anomalies, outlines area 225 (45 x 5 km^2) with >100 ppb

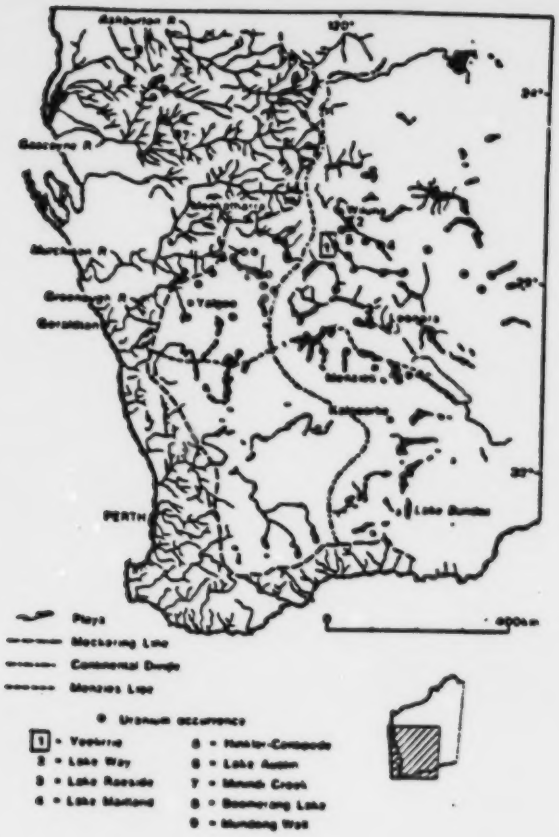


Figure 3-1 Site Location, Yeelirrie, Australia

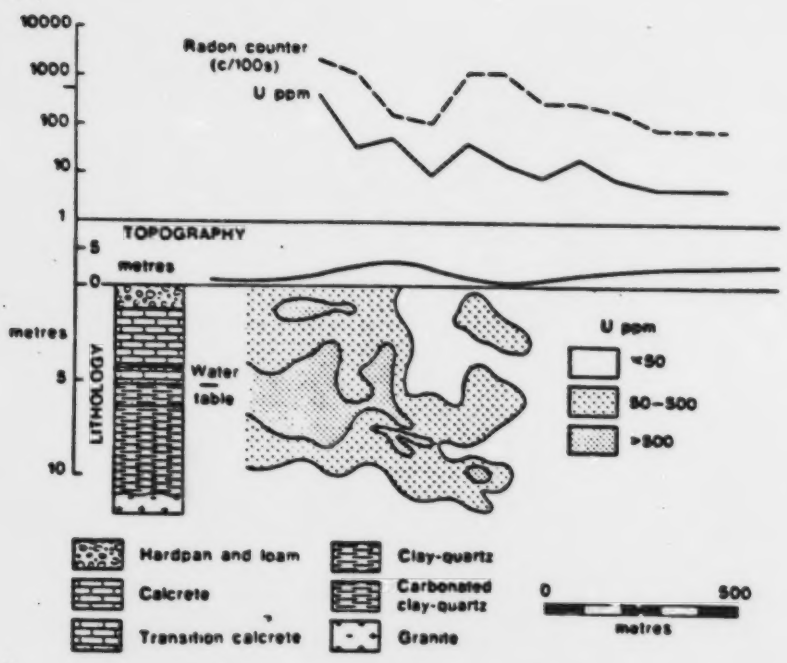


Figure 3-2 Cross-Section at Yeelirrie, Australia

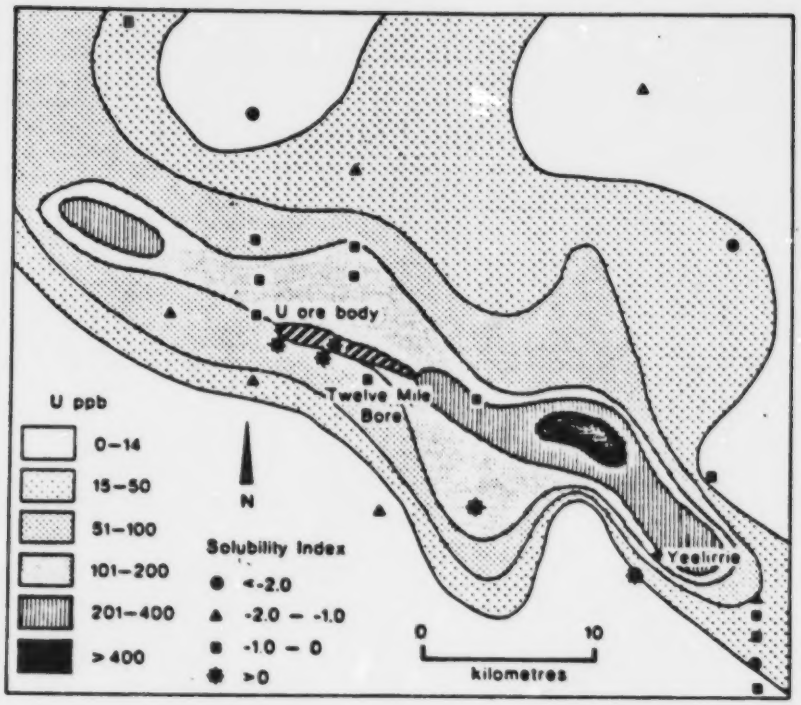


Figure 3-3 Groundwater Results, Yeelirrie, Australia

SITE 4
FORSTAU, AUSTRIA

References

Smith, A.Y., Camerson, J., Barretto, P.M.C. 1976. Uranium Prospecting In Austria. In: Proceedings on Exploration of Uranium Ore Deposits, Proceedings of a symposium, Vienna, 29 March - 2 April, 1976, IAEA, pp. 657-670.

This study presents the results of several geochemical and radiometric exploration techniques tested in an area of known uranium mineralization. The techniques used were geochemical analyses of heavy minerals, stream sediments, stream waters and soils and radiometry of stream sediments and soils.

Site Description

The area sampled was 200 square kilometres and it is situated between Radstadt and Schladming (Figure 4-1). The topography is mountainous, rising from 730 m at Schladming to over 2000 m between the Preunegg and Forstau valleys. The area is cut by a number of northward flowing streams that drain into the Enns River.

Within the Forstau area, at the time of the study, a uranium deposit was being developed by mining companies. The rocks of the area are metamorphosed sedimentary rocks such as schists and quarzite as well as limestone (Figure 4-1). The rocks have a east-west strike and dip steeply to the north. The mineralization is found in the sericite-quartz phyllite. Pitchblende is the uranium mineral and it is found in the phyllite cleavages. It was stated that it was assumed that the original uranium distribution was related to the bedding.

Uranium Anomaly Descriptions

A summary of the uranium concentrations in the rocks, stream sediments and waters and soil is presented in Table 4-1. The extent of any anomalies is provided in this table.

Uranium Rock Anomalies:

The ore body lenses vary in length from 10 to 100 m. The ore zone, based on surface radioactivity has been traced for several kilometres on both the east and west sides of Forstau valley. No secondary mineralization has been observed on ground surface or below. The location of an existing uranium mine near Forstau is shown in Figure 4-1. No information on the uranium concentrations in this deposit was provided.

Sediment Anomalies:

At a low sampling density of 1 sample per 5 square kilometres, heavy mineral samples do not indicate uranium mineralization (Figure 4-2, uranium mine, third stream from the left). This result was explained by the absence of secondary uranium mineralization in the area which itself illustrated the lack of surface chemical weathering since mountain glaciation.

Sampling at a higher density (approximately 16 samples per square kilometre) of stream sediments gave better results. As shown in Figure 4-3, the known mineralization (uranium mine) was not delineated but another area east of it was shown to have anomalous sediments. The results shown for the geochemical analyses were similiar to those for scintillometer readings. These results were interpreted as suggesting either that the known ore-bearing sericite-quartz phyllite may not be the most important unit or that this unit may be repeated in a fold system not yet shown by geologic mapping. Results of the uranium concentrations and radioactivity measurements of the streams sediments are listed in Table 4-1. There is a difference in size of the anomalies outlined by these two methods due to the different thresholds used.

Stream Water Anomalies:

Some streams have concentrations that are anomalous (>3 ppb). The authors suggest that an anomalous area is 20 km^2 (4 x 5 km^2). This value has not been included in the table as the size of the anomaly because of the low sample density used. The anomalous area covers the host rock as well as other rock types (Figure 4-3). The authors state that even at low sampling density (1 sample per 5 square kilometres), this hydrogeochemical technique outlines areas of interest for uranium.

Soil Anomalies:

A detailed soil survey (Figure 4-4) was carried out over a mineralized zone. The location of this survey is shown in Figure 4-3 as the square on the second stream from the right (Preunegg). This area had a steep slope of 30 degrees and soil thicknesses of up to 2 m. Although there are anomalous results (i.e. greater than 3.0 ppm) the authors suggest that the results are not indicative of mineralization. This is because the soil anomalies occur along streams in which numerous springs and streams are present. The anomalies seem to be due to hydromorphic dispersion in a fractured rock groundwater zone. The varied flow paths of the discharging groundwater do not allow for locating the source of the mineralization in the rock.

TABLE 4-1
URANIUM CONCENTRATIONS AND ANOMALIES AT FORSTAU, AUSTRIA

Media	Concentrations	Anomalies
ROCK:		
study area 200 km^2 (20 x 10 km^2) mineralization in a sericite-quartz-phyllite		ore bodies vary in length from 10 to over 100 m
STREAM SEDIMENT:		
1) heavy mineral samples (pan concentrates)	n = 38 0.2 - 7.2 ppb	not useful for outlining anomalies
2) stream sediments chemical anlayses	n = 323 arith. mean = 1.68 ppm 0.5 - 15 ppm	19 anomalies >4 ppm (total area approx. 7 km^2), anomalies range from 0.25 to 1.5 km^2, approx. avg. 0.5 km^2; known uranium mineralization not anomalous
scintillometer readings	n = 323 arit. mean = 19 cts/min <45 - >130 counts/min	13 anomal >100cts/min (total area approx. 17 km^2) anomalies range from 0.25 to 7 km^2 main zone of increased radioactivity does not fall on area of known mineralization

STREAM WATERS: 1 sample per 5 km^2	n = 33 mean = 1.9 ppb 0.2 - 5.0 ppb	7 samples have anomalous levels (>3.0 ppb), these sites overlie the host rock as well as other rock types
SOILS: nearby Preunegg valley nearby stream water, stream sediment and radioacivity anomalies, study area 18000 m^2 (150 x 120 m^2)	n = 80 arith. mean = 1.2 ppm 0 - 4.8 ppm	5 anomalies >3 ppm (total area approx. 135 m^2) anomalies range from 5 to 75 m^2, approx. avg 15 m^2

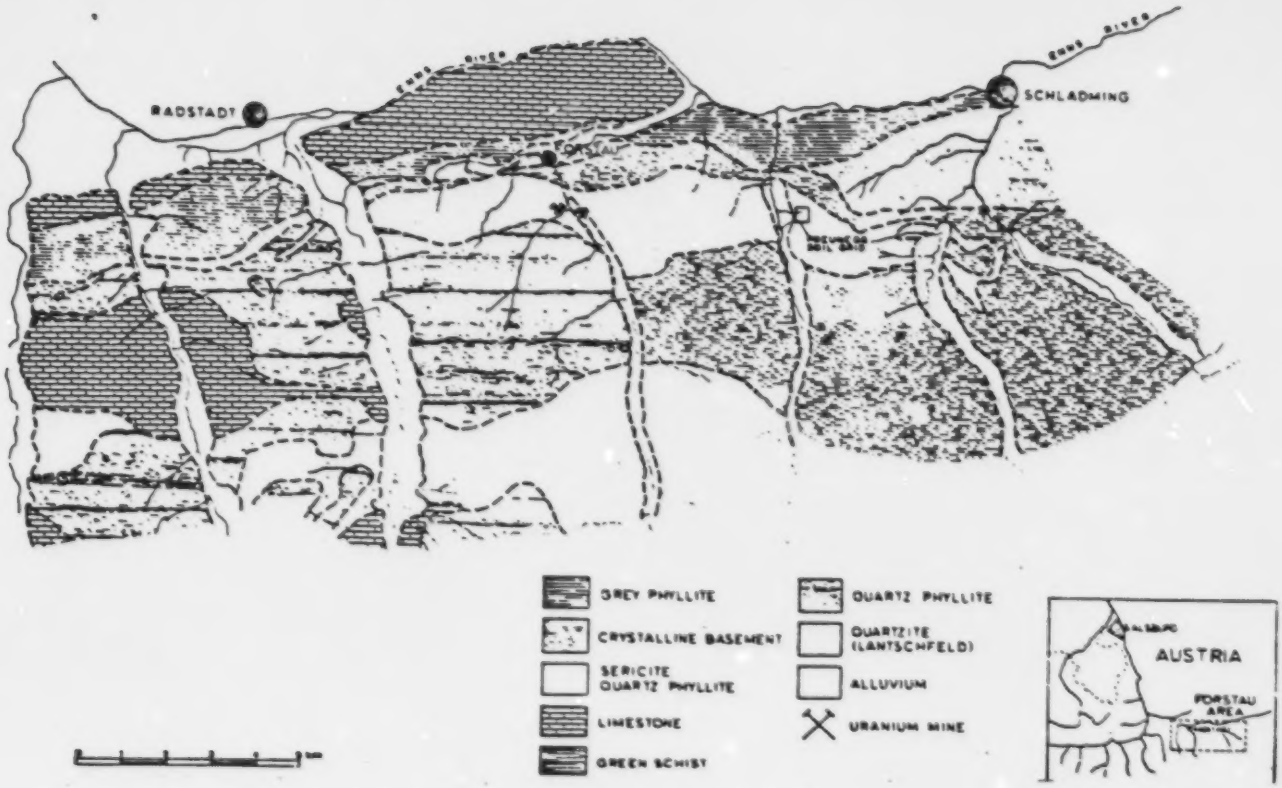


Figure 4-1 Site Location, Forstau, Austria

Figure 4-2 Heavy Mineral and Stream Water Results
Forstau, Austria

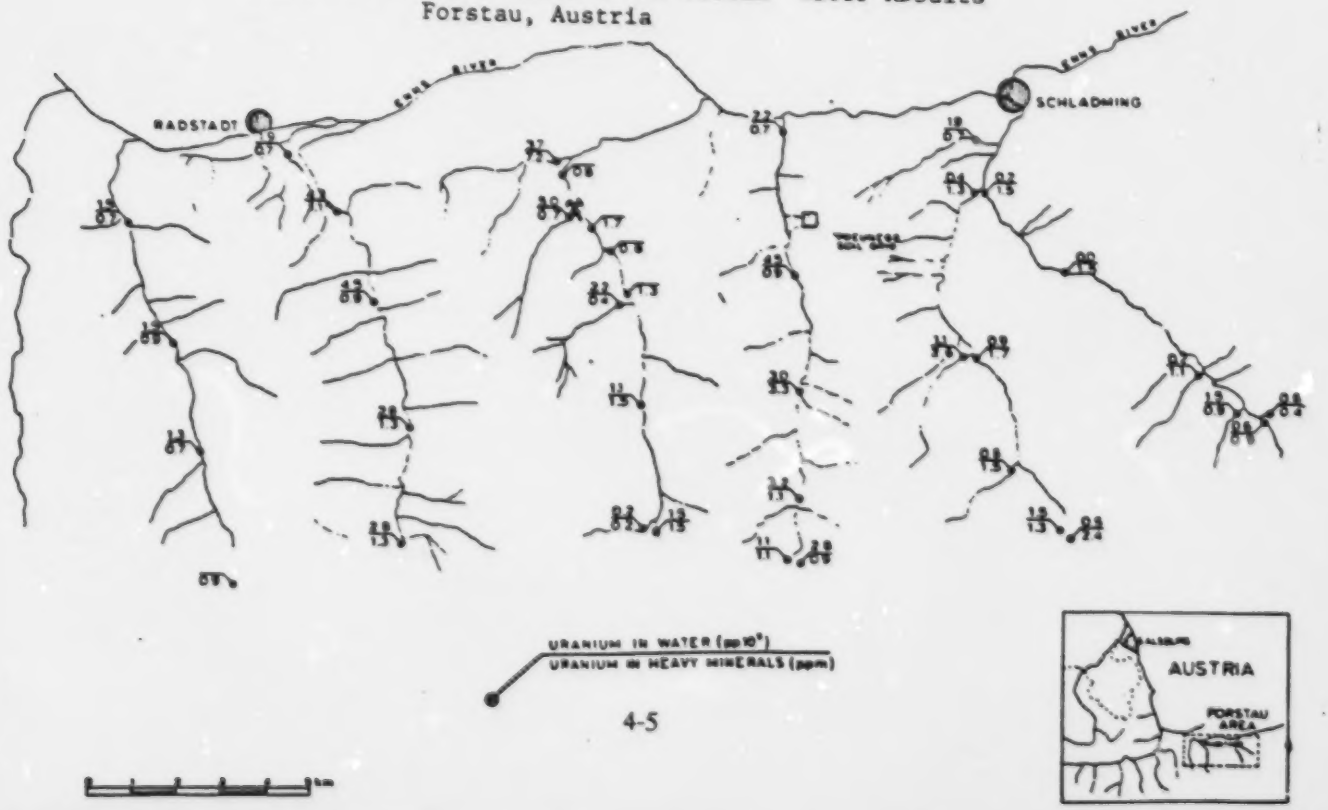


Figure 4-3 Stream Sediment Results, Forstau, Austria

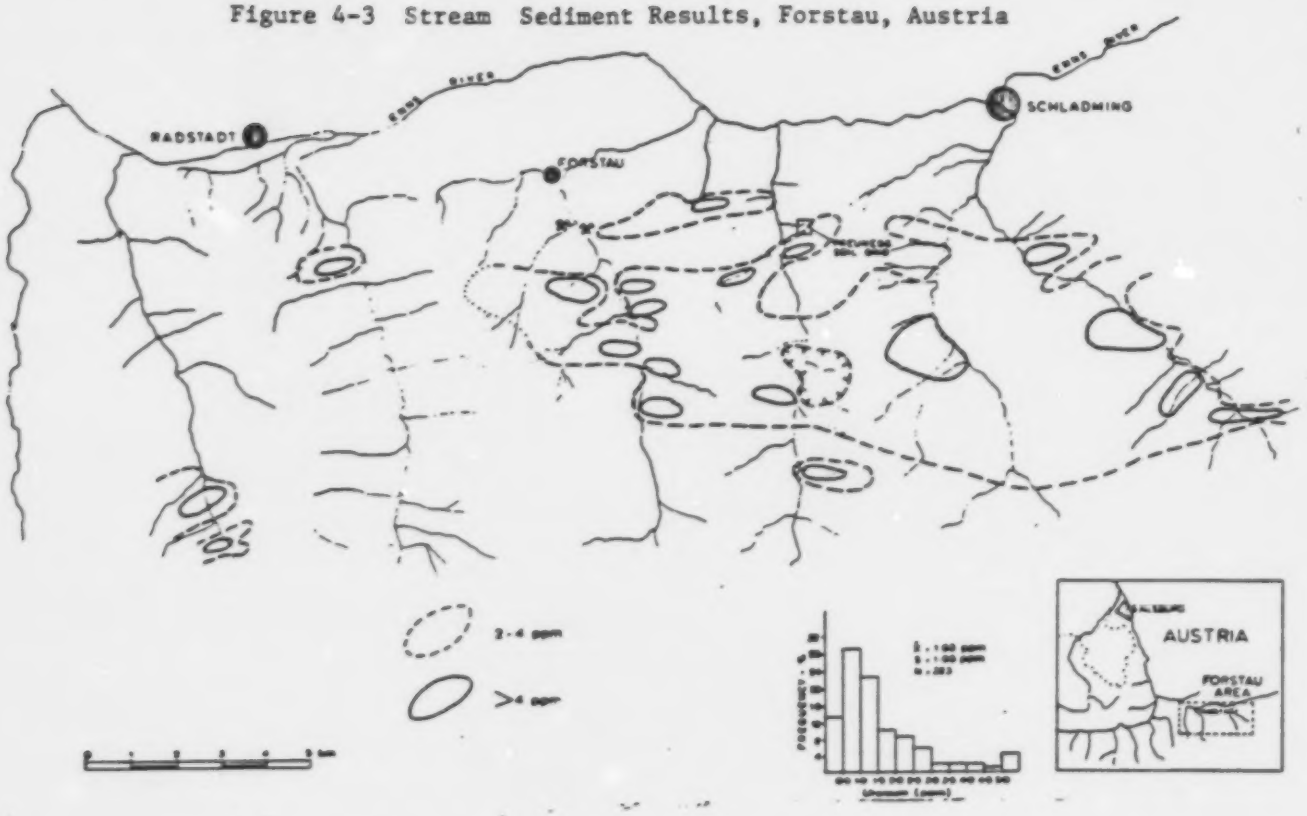
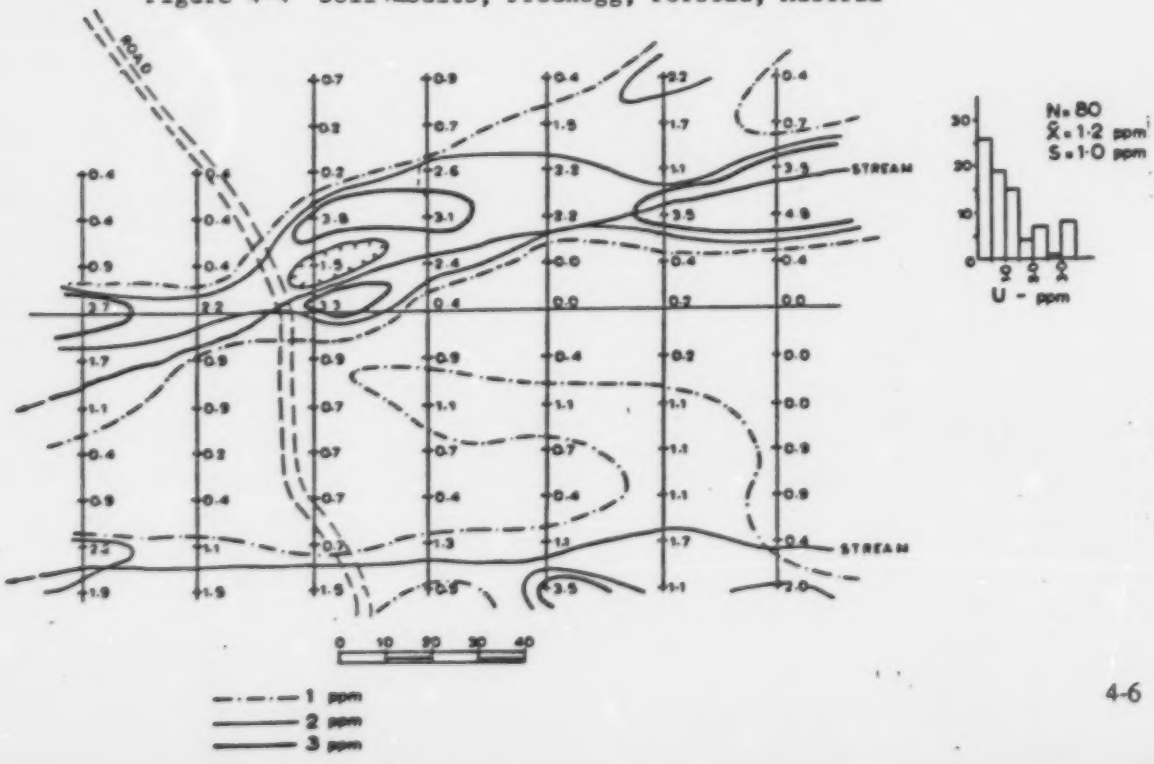


Figure 4-4 Soil Results, Preunegg, Forstau, Austria



SITE 5
BANCROFT, ONTARIO

This site has been included because of the type of geology in the area even though it is also a mining area.

References

Chamberlain, J.A. 1964. Hydrogeochemistry of uranium in the Bancroft-Haliburton Region, Ontario. Geological Survery of Canada Bulletin 119, 19 pg.

The results of a 4500 km^2 survey of surface waters are provided. The large scale of the study gives large anomalies. Data is also provided on uranium concentrations in sediments and waters draining a mine in the study area.

Darnely, A.G., Grasty, R.L. 1971. Mapping from the air by gamma-ray spectrometry. CIM Special Vol. 11: 485-500.

The study provides results of a airborne gamma-ray survey over a 1000 km^2 area.

Morse, R.H. 1971. Comparison of geochemical prospecting methods using radium with those of radon and uranium. CIM Special Vol. 11: 215-230.

Uranium concentrations in sediments and surface waters from a 144 km^2 area are presented.

Robertson, J.A. 1981. The uranium deposits of Ontario - Their distribution and classsification. OGS Miscellaneous Paper 86, 37. pg.

A description of the uranium occurrences in the Bancroft area are provided in this report.

Sheppard, M.I., Olchowy, L., Mayoh, K.R. 1981. Uranium, thorium, radium, and arsenic concentrations of plants and soils of the Precambrian Shield: A preliminary study. AECL TR-159, 32 pg.

Uranium concentrations in plants and soils from the Bancroft area are listed in this paper. The locations of the samples are not provided in this document. A general description of the Bancroft area is included.

Site Description

The approximate location of the Bancroft area is shown in Figure 5-1. The Bancroft area occurs within the Grenville Province of the Canadian Shield. The geology of the area is comprised of metasediments and plutonic rocks. This area has been well prospected and has well documented radioactive occurrences. The Bancroft area of Eastern Ontario is well known for its uranium occurrences. They are several mines in the area; Faraday Mine and Grey Hawk Mine have operated in the past and the Madawaska Mine was actively mining and millling.

Within a 15 kilometre radius of Bancroft, approximately 60 % of the area is outcrop. The remaining portion of the land is covered with podzolic and luvisolic soils. The soils present in the Bancroft area are residual. Adjacent to depressional areas and streams, a small portion of the land is covered by organic soils. The Bancroft area is heavily forested, with maple, birch, spruce and aspen predominating. The area appears to have well developed drainage systems.

The radioactive deposits occur in granite and syenite pegmatites, in calc silicates and in hydrothermal calcite-fluorite-apatite veins.

Uranium Anomaly Descriptions

A summary of the uranium concentrations in the rocks, stream sediments, surface waters and soils and plants is presented in Table 5-1. The extent of any anomalies is provided is this table. The studies reviewed were generally regional studies with only a few sketchy site studies.

Uranium Rock Anomalies:

The Bancroft area mineralization is reported as being a metamorphic type deposit with uraninite and uranothorite the primary ore minerals. It is not possible to outline the extent of the rock anomalies because of the high number of deposits included in the regional studies. It has been reported that pegmatite ore bodies are generally small. At Bancroft there is a secondary geochemical halo greater than 550 square kilometres.

Sediment Anomalies:

The uranium anomalies in clastic sediments is reported to correspond more accurately to rock type and distribution of uranium deposits than to organic sediments. The results of this study by Morse (1971) is shown in Figure 5-2; it was concluded that stream sediments are more useful for prospecting than stream waters.

Surface Water Anomalies:

A regional study of creeks, rivers, lakes and swamps over a 4500 square kilometre area indicated the following for the high uranium values: 1) they are of limited extent, with high values decreasing to background levels within a hundred metres or so of the peak anomaly and 2) they are spatially and genetically related to bedrock zones of enrichment. The exception to this is Bow Lake into which Faraday mine, tailings and plant drain. Water samples from this lake were relatively constant at 50 ppb. Figure 5-3 shows an example of the decrease of uranium in short distances from a concentrated source. Chamberlain (1964) concluded that because there are so many radioactive occurrences and also because of the mining history of the area, it was not possible at the regional level to outline the true extent of the anomalies.

The results of a less regional study of 144 square kilometre area are discussed in Table 5-1 and are shown in Figure 5-4.

Soil Anomalies:

The two anomalies (> 8ppm U) outlined by the gamma ray spectometry correspond to plants of Bicroft Mine and Faraday Mine.

The results of the soil traverses over Faraday Mine indicated that the B horizon could be useful for detailed prospecting for uranium. It was reported that the A horizon is not useful.

Plant Anomalies:

Refer to Table 5-1.

SITE 5 URANIUM CONCENTRATIONS AND ANOMALIES AT BANCROFT, ONTARIO

Media	Concentrations	Anomalies
ROCKS: Radioactive occurrences in granite and syenite pegmatites, calc silicates and hydrothermal calcite-fluorite-apatite veins	numerous radioactive occurrences and mines, i.e. Bancroft camp produced 4,600 tons with ore grade from 0.02 to 0.2 %	no specific anomaly outlined
SEDIMENT: 1) organic and clastic sediments over 144 km^2	n = 235 excluded values from tailings pond at Bicroft and Faraday mines clastic <0.6 - >33 ppm organic <1.0 - >90 ppm	uranium in clastic sediment corresponds more accurately to rock type and distribution of uranium deposits than in organic sediment clastic sediment: b.g. assumed <0.6 ppm 7 anomalies 4.5 - >33 ppm a) 8 km of stream near Bicroft mine b) 3.2 km of stream near Greyhawk mine c) other 5 just one sample

2) samples collected from drainage from tailings (Amalagamated Rare Earth Mines Ltd), into a swamp and into a lake	no detailed study, tailings 0.60 ppm swamp .14 & 0.04 ppm lake inlet 0.003 ppm lake 0.002 ppm	organic sediment: b.g. assumed <1.0 ppm 17 anomalies 12 - >90 ppm a) 8 km of stream near Bicroft mine b) 3.2 km of stream near Greyhawk mine c) others (15) just one sample indication of decrease in uranium concentrations from a source (tailings) to discharge (lake inlet) 121 m apart

SURFACE WATERS:		
1) Regional: creeks and rivers, lakes, and swamps over 4500 km^2 1 sample/3.3 km^2	n = 1,110 76 samples contaminated <1 - 700 ppb detection limit 1 ppb average 1.6 ppb (avg for 76 samples 15.1 ppb)	b.g. 1 -2 ppb anomalies estimated a) 3500 km^2 for >10 ppb b) 30 km^2 for >60 ppb
2) Local: a) streams and lakes, ponds, swamps, and springs from a 144 km^2 area	n = 235 <0.6 - >2.7 ppb excluded values from Bicroft and Faraday mines	levels in lake water cannot be correlated with uranium deposits or rock type (order of usefullness for prospecting is stream sediments > streams > lakes) anomalous > 1.6 ppb 9 anomalies shown a) 1 km of stream near Bicroft mine b) 1.2 km of stream near Greyhawk mine c) others (7) only 1 or 2 samples
b) Amalagamated Rare Earth Mines Ltd.	n = 27 1 - 720 ppb adit: 200 - 500 ppb tailings: 600 - 720 ppb swamp: 320 - 640 ppb lake inlet: 20 ppb lake: 1 - 2 ppb	b.g. 1 - 2 ppb indication of decrease in uranium levels from a source (tailings) to discharge (lake inlet)

SOILS: 1) airborne gamma ray spectrometry over approx. 1000 km^2 2) 2 baselines over Faraday ore body (each 213 m long)	n = ? <0.8 - >8.0 ppm n = 46 n = 25 A horizon n = 21 B horizon A hor. <1 - 500 ppm B hor. <1 - 70 ppm	2 anomalies 5 - >8 ppm (total area 8 km^2) both 4 km^2 (0.8 x 4.8 km^2) no anomalies outlined
PLANTS: no location provided	n = ? <5 - >50 ug/g ash	no anomalies outlined

Figure 5-1 Site Location, Bancroft, Ontario

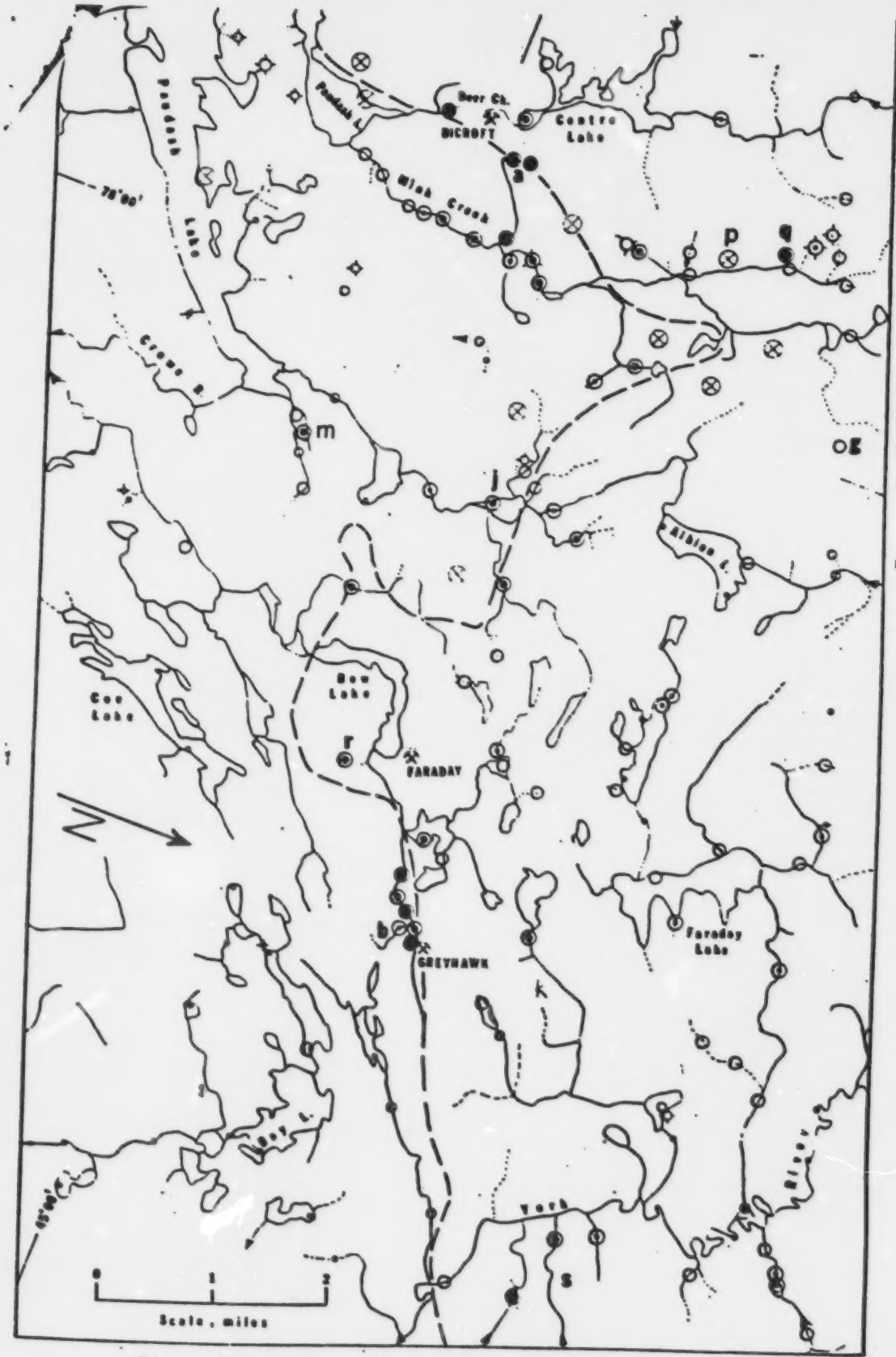


Figure 5-2 Stream Sediment, Bancroft, Ontario

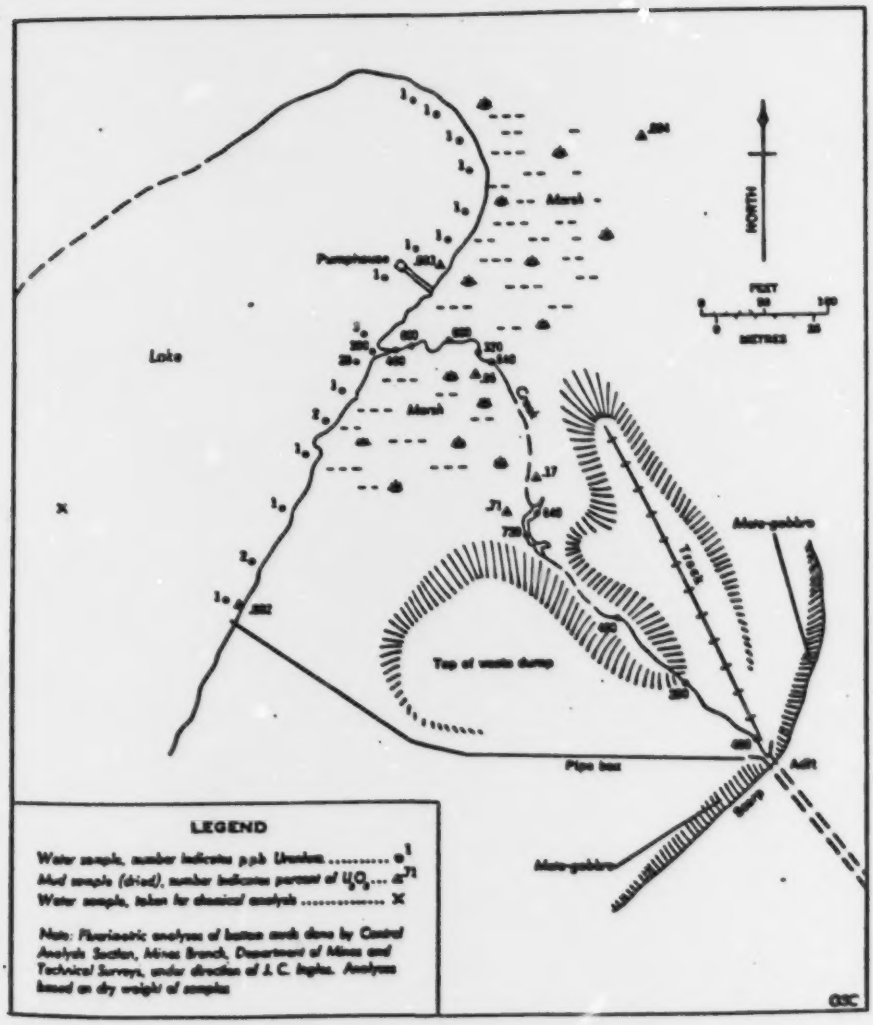


Figure 5-3 Surface Water Near Faraday Mine
Bancroft, Ontario

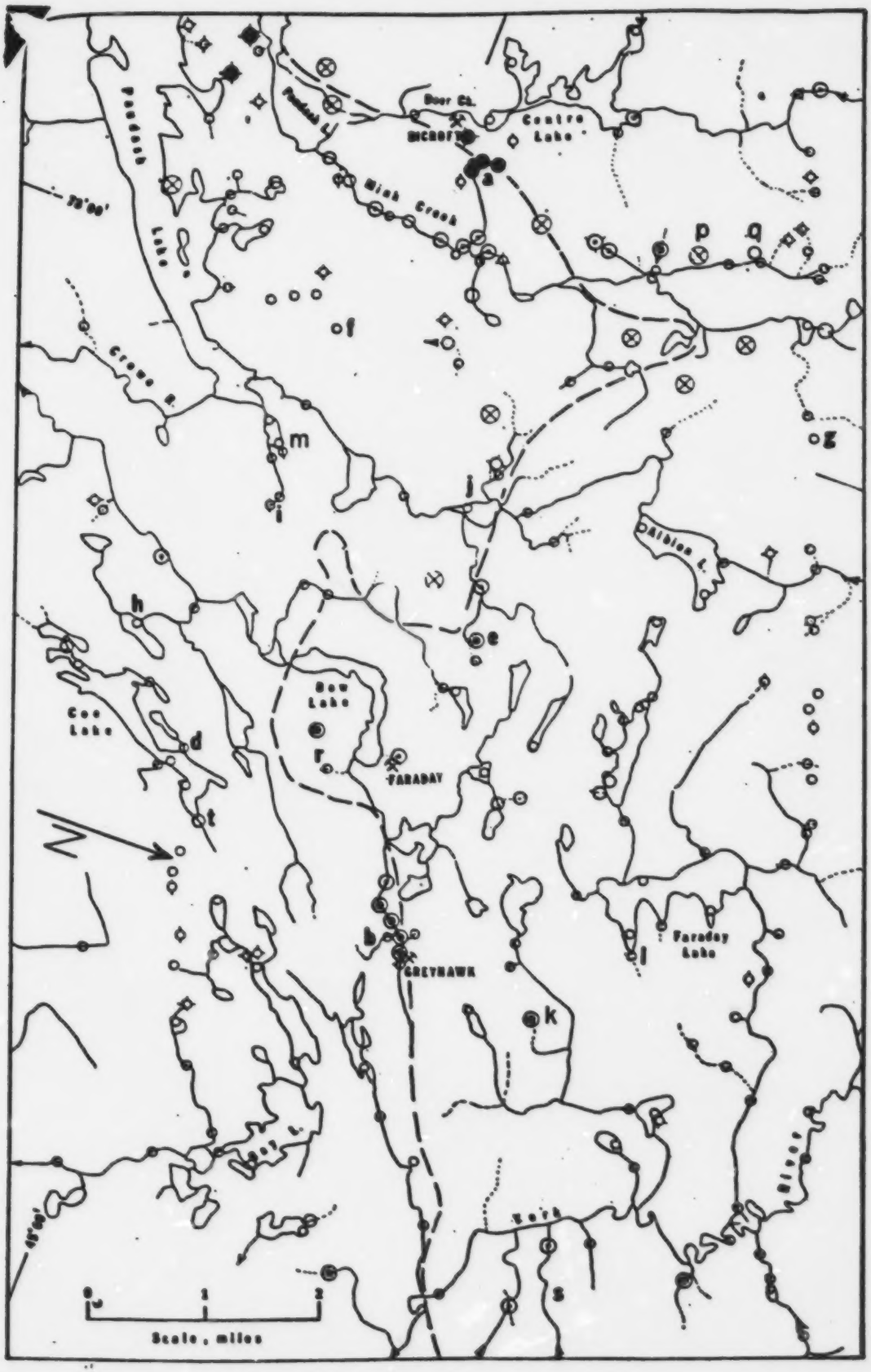


Figure 5-4 Surface Water, Bancroft, Ontario

SITE 6
BLIZZARD DEPOSIT, OKANAGAN BRITISH COLUMBIA

References

Boyle, D.R. 1982. The Formation of Basal-Type Uranium Deposits in South Central British Columbia. Economic Geology 77: 1176 -1200.

This study provides information on the mineralization and rock concentrations in the Blizzard deposit.

Environcon Ltd. 1980. Blizzard Uranium Property Baseline Environmental Studies. Volumes 1 - 4.

Information on uranium in rocks, sediments, surface waters, groundwaters, soils and plants is provided in this reference. The study covers an area of a 10 kilometre radius from the ore body. The Blizzard Property is approximately 18 square kilometres. The report provides useful information on the concentrations but not on the extent of anomalies. Raw data and separate maps of sample locations are provided. It would be possible to use this information to construct anomaly basemaps although for the present study, the sampling density was too coarse. The report provides data on other radionuclides (i.e. lead, polunium, radium, and thorium).

Site Description

The Blizzard uranium deposit is found within the Okanagan area of British Columbia (Figure 6-1). It is within an area which has been labelled by researchers as Lassie Lake. It is about 50 km southeast of Kelowna. Within this area, several uranium deposits have been found but this study has concentrated only on the Blizzard deposit.

The area is within the Okanagan Highlands, which is a region of moderate relief with plateau areas separated by incised river and creek valleys. For the Blizzard deposit, elevations vary from 1800 m.a.s.l. in the north to 790 m.a.s.l. in the east. The property is situated within a watershed divide between the Kettle and West Kettle Lakes. There are several groundwater flow systems with local discharge area in the northwest and southeast ends of the property. These sediments are reported to overlie major fault zones in the Okanagan Highland Intrusive Complex. The property lies within the Eastern Tectonic Belt of the Western Cordillera. Glacial overburden is present with thicknesses appearing to be less than 10 m. The climate is a mild, continental temperate regime with no significant amounts of precipitation. The area was forested with lodgepole, pine and spruce although a major portion has logged.

The uranium mineralization is present in paleosediments underlying a basalt cap. A typical cross section is provided as Figure 6-2. The mineralization occurs in greatest proportions in mudstones and/or sandstones. The uranium is thought to have been leached from surrounding rock and carried by groundwater and deposited in the sedimentary rocks of the paleochannel.

Uranium Anomaly Descriptions

A summary of the uranium concentrations in the rocks, stream sediments, surface waters, ground waters, soils and plants is presented in Table 6-1. Although there is information on the uranium concentration in each environment, the sampling density does not readily allow for outlines of anomalies. Figure 6-3 illustrates the study area. Generally there is no wide spread dissemination of uranium in the biosphere. The extent of the anomalies is controlled by the groundwater infiltrating through the ore bearing sedimentary rocks.

Uranium Rock Anomalies:

The deposit occurs as four distinct lenses and together they extend the length of the paleochannel (Figure 6-4). The deposition of the ore is reported to be controlled by the porosity and permeability of the sedimentary rocks.

Sediment Anomalies:

Sediments collected from streams have low levels of uranium (i.e. 2 - 6 ppm). Lake sediment samples typically have higher values (range of 3 to 21.6 ppm). A lake which received drainage directly from the orebody had the lowest sediment concentration.

Groundwater Anomalies:

Infilitrating waters pass through the fractured basalt cap and flow into the ore bearing sedimentary rocks. Groundwater within the sedimentary rocks is deflected along the strike of the deposit towards the north and south. Groundwater discharge areas are present along the northern and southern extents of the orebody as well as along the sides. Uranium concentrations in these discharging groundwaters (no value provided) are reported to confirm that the ore is being leached. Uranium was listed as one major element species of the groundwater. The highest concentrations were from stations on the orebody. The groundwater levels were 30 to 40 times higher than in the surface waters. The concentration in present day groundwaters from the source rocks is reported to have ranges of averages of 4.5 to 37 ppb.

Surface Water Anomalies:

It was reported that surface waters may be separated from the groundwater discharge areas by organic clays and silts. Drainage in the immediate vicinity appears to be enriched in uranium, however the anomalies are quickly reduced to background levels. The absence of anomalous values for the surface waters in the local area has been reported as unexpected as the Blizzard deposit is situated well above the water table and should be subject to effects of leaching by surface waters.

Soil Anomalies:

There is some variability in the soil results. Generally the highest concentrations are in the vicinity of the orebody. A high region exists to the east of the orebody; 13.8 ppm at 3 kilometres to the east. Generally soils off the orebody were reported to have concentrations of 3 to 7 ppm.

Plant Anomalies:

Twenty seven terrestrial and two aquatic species were sampled. The results of the terrestrial plant analyses were described in several ways, i.e. distance from orebody, species or plant type. The uranium concentrations are less at a distance of 10 kilometres or more from the orebody than that of similiar plants collected nearer the ore body. The highest concentration was found in Asters (Aster sp.). Asters collected from the orebody contained 420 ppb (soil sample had 390 ppb of uranium).

The aquatic plants contain much higher uranium levels than the terrestrial vegetation i.e. up to 2.1 ppm. Water lily samples (Nuphar) show a decrease in uranium concentration with distance from the orebody. The plant levels did not correlate with levels either in the water or in the sediment. A notable difference in concentration was observed between the sring and summer samples but without a consistent trend.

TABLE 6-1
URANIUM CONCENTRATIONS AND ANOMALIES AT BLIZZARD DEPOSIT, OKANAGAN BRITISH COLUMBIA

Media	Concentrations	Anomalies
ROCK: mineralization in paleo-fluvial sediments, largest proportion of uranium in mudstones and sandstones, most of deposit is covered by basalt cap up to 40 m thick uranyl and uranous phosphate minerals	ore reserves est. 4,020 metric tons of U (based on avg. ore grade of 0.183 % U) typical concen. in drill holes 100 - 30,000 ppm unmineral. 2 - 10 ppm	situated in a paleochannel 1.6 km long, max. width 120 m with a average thickness of 10 - 20m
SEDIMENTS: collected from within 10 km radius of orebody	n = 10 mean 10.3 ppm range 2.1 - 21.6 ppm	no anomalies outlined
SURFACE WATERS: collected from lakes and streams within 10 km radius of the orebody	n = 115 mean 0.44 ug/L range 0.05 -1.70 ug/L	not possible to outline anomalies, but high concentrations possibly restricted to orebody, estimate 0.10 km^2
GROUNDWATERS: collected from within Blizzard property (18 km^2)	n = 25 mean 18.79 ug/L range 0.65 - 85 ug/L	no anomalies outlined but highest values over orebody, estimate 0.20 km^2

SOILS: 1) collected on or around (within 13 km) of orebody 2) collected same area, looking at soil types; upland till, lowland till, lowland alluvium	n = 64 range 1.5 - 390 ppm (for spring/summer) typical 5 - 15 ppm (for spring time) n = 11 mean 25 ppm range <0.5 - 125 ppm	higher values for east drainage off orebody, values 3 - 7 ppm for values off orebody, estimate 0.10 km^2 greatest levels in lowland alluvium
PLANTS: 1) Terrestrial samples 27 species sampled from sites within 13 km of orebody 2) Aquatic samples 2 species sampled from sites 3 to 12.5 km from orebody	number of sites = 31 n = ? (>40) range 0.005 - 420 ppb (for ash) n = 9 mean 0.44 ppm (ash) range 0.075 - 2.10 ppm (for ash)	sample density does not allow for delineation of anomalies, estimate 0.1 km^2 sample density does not allow for outline of anomalies

FIGURE 6-1

LOCATION MAP Blizzard, B.C.

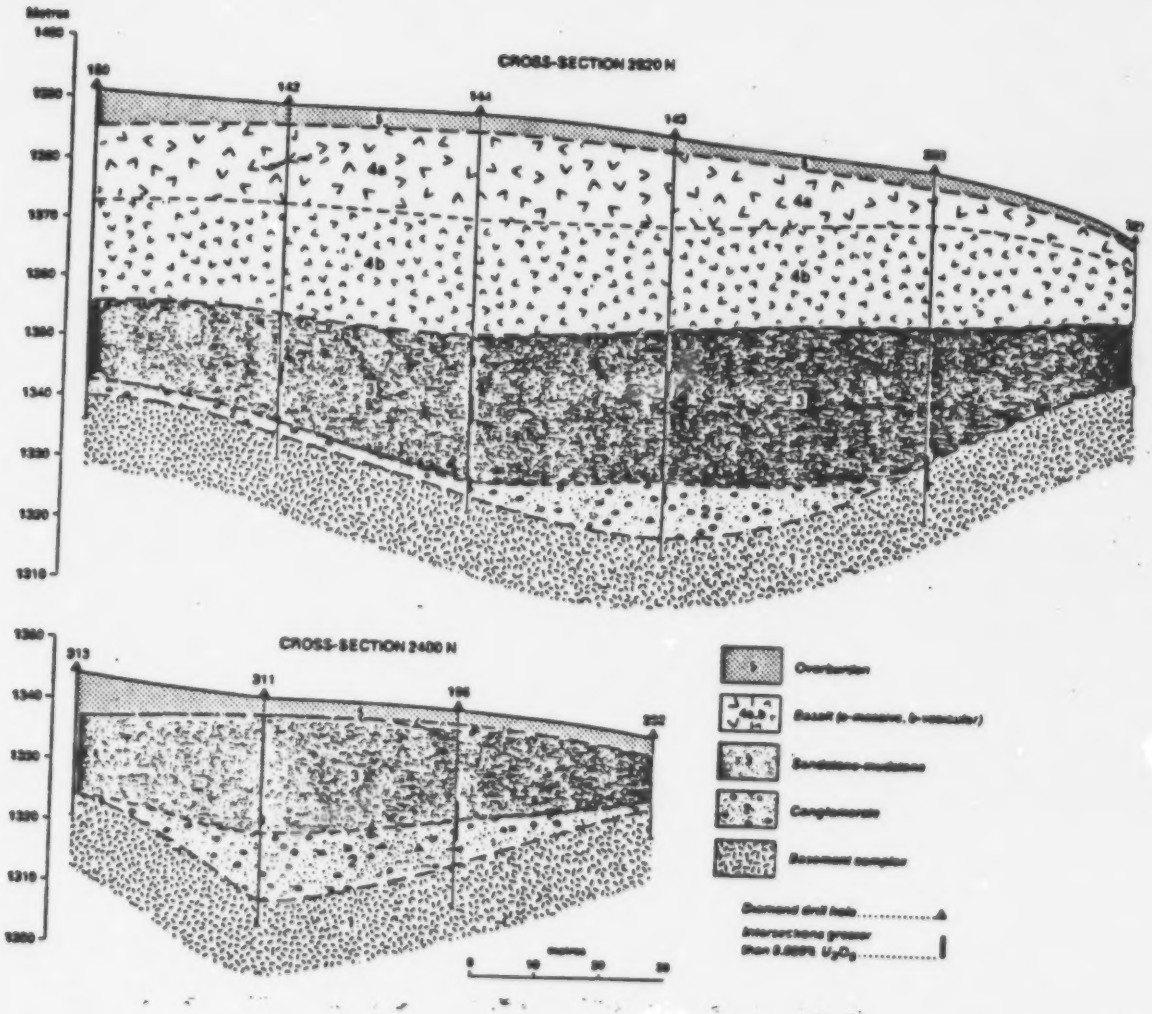
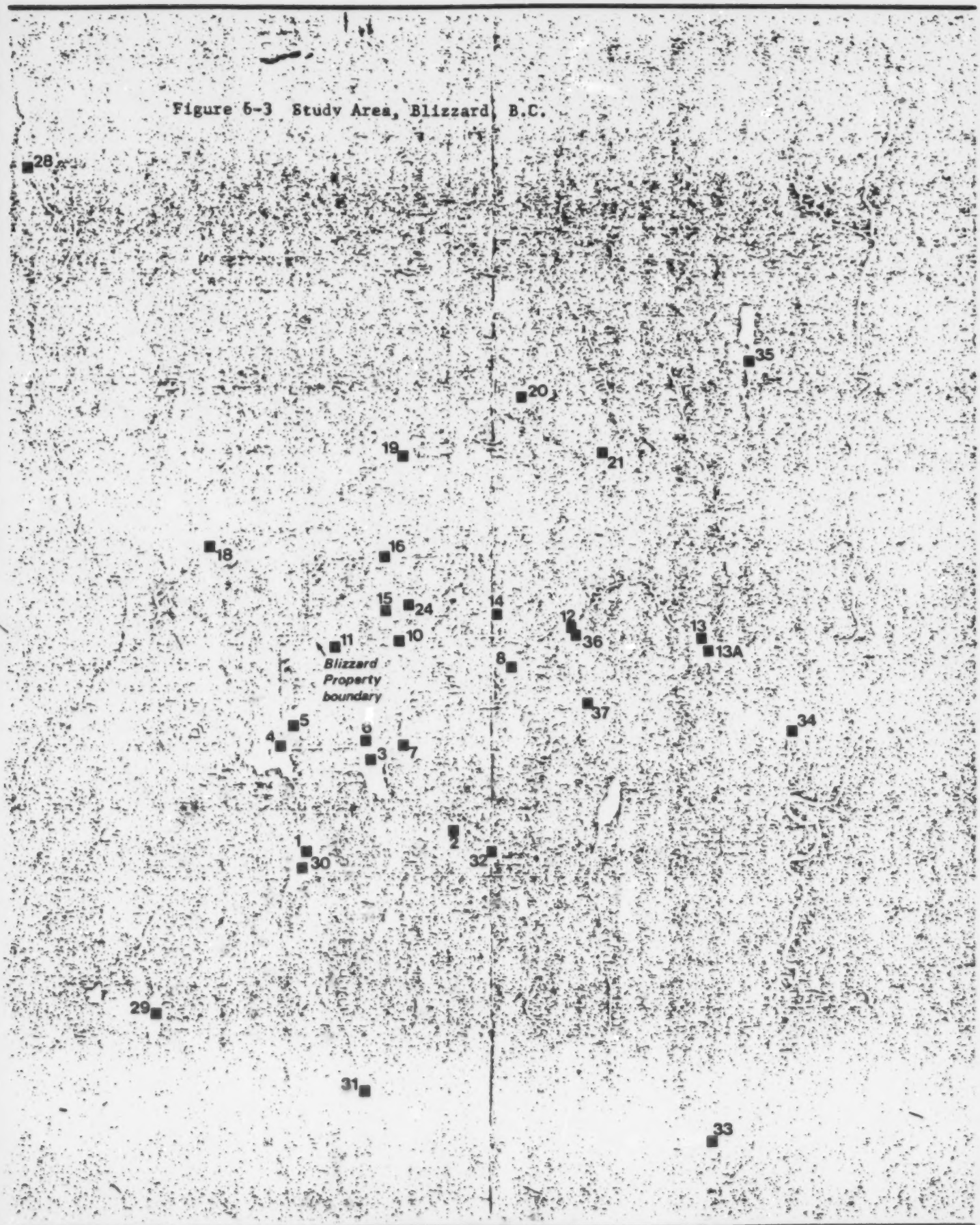
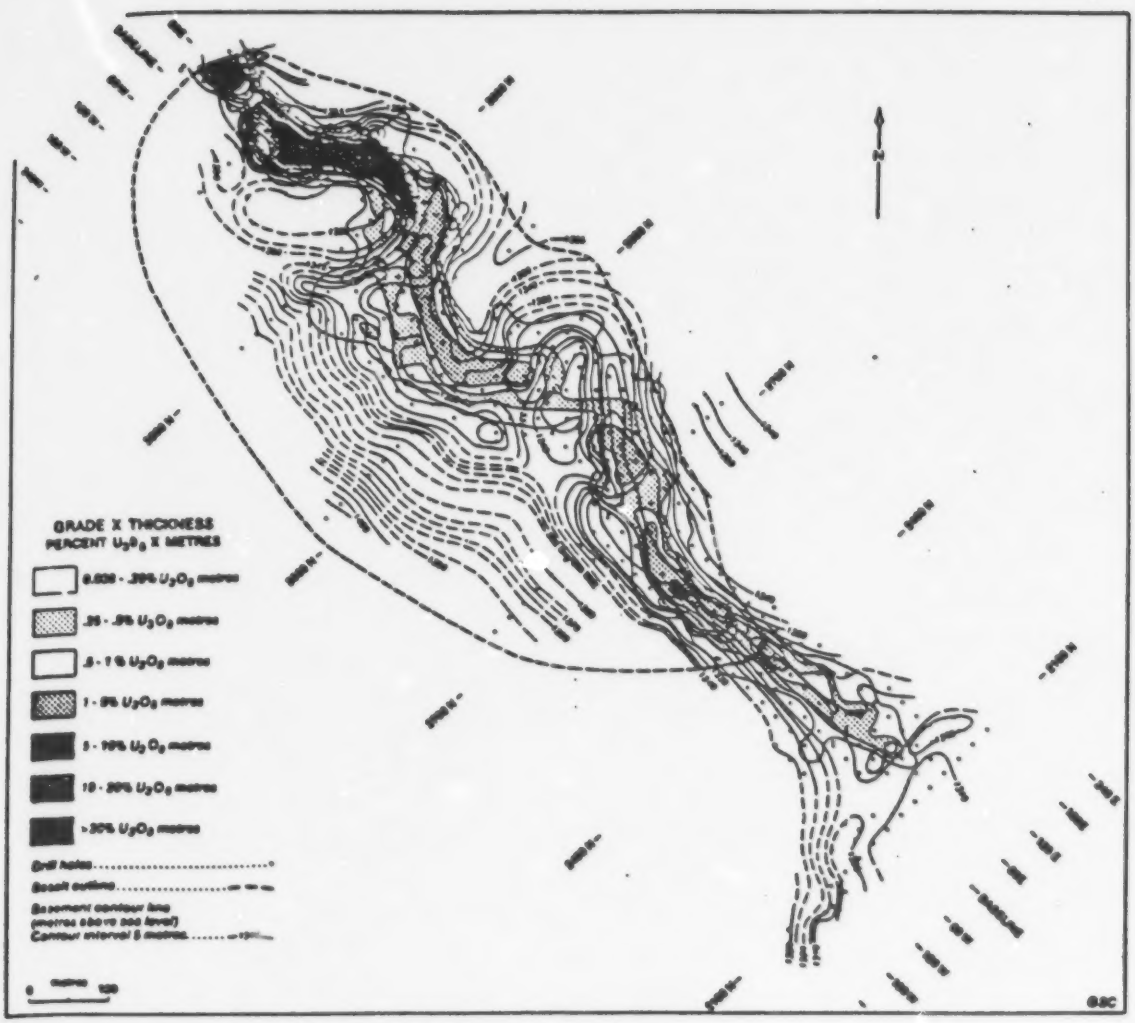


Figure 6-2 Cross-Section, Blizzard, B.C.

Figure 6-3 Study Area, Blizzard, B.C.





Grade X thickness plot of the Blizzard uranium deposit.

Figure 6-4 Rock Results, Blizzard, B.C.

SITE 7
KAIPOKOK REGION, LABRADOR, NEWFOUNDLAND

This site has only a limited amount of information but has been included because of the geology of the area.

References

Beaven, A.P. 1958. The Labrador uranium area. In: Proceedings of the GAC, December, 1958, pp. 137-145.

The reference provides general information on the geology and uranium occurrences in the Kaipokok Uranium Area.

Meyer, W.T. 1969. Uranium in lake water from the Kaipokok Region, Labrador. Quarterly of the Colorado School of Mines 64(1): 377-394.

Lake sediments from a 1500 km^2 area, 15 km south of the Kitts deposit were analyzed for uranium. The results are presented as a figure only and are based on a rolling mean analysis of the data. Water results of small study of a drainage system 32 km^2 in area in the vicinity of the Kitts deposit are included.

Minatidis, D.G., Slatt, R.M. 1976. Uranium and copper exploration by nearshore lake sediment geochemistry, Kaipokok region of Labrador. Journal of Geochemical Exploration 5: 135-144.

Lake sediments collected from an area 162 km^2 in size are provided. The location of this study area is difficult to determine but it is within the Kaipokok area in the vicinity of the Michelin occurrence.

Site Description

The Kaipokok Uranium area is approximately 5800 square kilometres. The area varies from rugged to flatter terrain, from wooded to barren areas, and with sedimentary, igneous, and metamorphic rocks. There is a predominant northeastern structural trend. The glacial history indicates that the ice flowed to the northeast. Bedrock exposures are sparse because of the vegetation cover and the presence of either ground moraines, abundant shallow lakes or bogs in kettles or in ice-scoured rock basins.

The Kaipokok area has been classified as a well defined uranium province with widespread mineralization in a variety of occurrences in diverse rock types. The Kitts occurrence (Figure 7-1) is situated in a band of argillaceous and volcanic rocks on the south shore of Kaipokok Bay. Two other named deposits, the Michelin and the Rainbow occurrences are mentioned.

Uranium Anomaly Descriptions

A summary of the uranium concentrations in lake sediments and surface/ground waters is presented in Table 7-1. The extent of any anomalies is provided is this table. The majority of the information is from two regional surveys. One is a lake water survey located approximately 15 km south of the Kitts deposit (1500 square kilometres, Figure 7-2) and the other is a lake sediment survey, not as clearly located but in the Kaipokok area and nearby the Michelin occurrence (162 square kilometres, Figure 7-3). The results from a small study of the concentrations in water from the Kitts deposit are also provided.

Uranium Rock Anomalies:

In the Kaipokok area more than 75 separate radioactive showings are present. The geology and the occurrence of radioactive showings in an area approximately 15 km south of the Kitts deposit is shown in Figure 7-2 (this area was sampled for lake waters). Uranium concentrations for the Michelin occurrence are reported to be 10 to 5400 ppm and for the Rainbow deposit 210 to 800 ppm. The location of the Michelin occurrence is shown in Figure 7-4a.

Overburden Anomalies:

Several radioactive boulder trains were discovered in the area nearby the Michelin camp (Figure 7-4a). No other information was provided on these boulder trains.

Sediment Anomalies:

Lake sediment anomalies from samples collected in the vicinity of the Michelin occurrence (Figure 7-4a and b) trend northeasterly with the regional strike and in some cases are reflection of surface exposure of mineralized areas. No relationship was found between clay and carbon contents and uranium concentrations.

Surface/Groundwater Anomalies:

The results of a small study of waters collected from the vicinity of Kitts deposit is shown in Figure 7-5. These result indicate the influence of organic matter (in the swamp) of decreasing uranium concentrations in water.

Results of a regional lake water survey 15 km south of the Kitts deposit have low values with a maximum of approximately 2 ppb (Figure 7-6). The results could not readily be correlated with airborne anomalies.

TABLE 7-1 URANIUM CONCENTRATIONS AND ANOMALIES AT KAIPOKOK REGION, LABRADOR

Media	Concentrations	Anomalies
ROCK: Kaipokok Uranium area 5800 km^2 (40 x 145 km^2), uranium occurrences in folded sedimentary and volcanic rocks, at Kitts deposit mineralization found in quartz-calcite veins and sheared argillite and andesite, majority of smaller showings are located in Precambrian quartzites		
LAKE SEDIMENTS: samples collected from 24 lakes in vicinity of the Michelin deposit, study area 162 km^2 (18 x 9 km^2)	n = 184 0 - 104 ppm	9 anomalies >4 ppm (total area approx. 30 km^2) anomalies range from 0.25 - 12 km^2, approx. average 3.5 km^2
WATERS: 1) orientation study at Kitts deposit study area approx 32km^2 (6.5 x 5 km^2)	n = 9 0.1 - 255 ppb	max. value 255 ppb from adit and ore dump, 3 km downgradient reduced to 1.7 ppb, b.g. approx. 0.4 ppb

2) regional study approx. 1500 km^2 (50 x 30 km^2), approx. 15 km south of Kitts deposit	n = approx. 250 <0.05 - approx. 2 ppb	b.g 0.1 ppb 2 anomalies >0.3 ppb a) approx. 13 km^2 (4 x 3.2 km^2) b) approx. 3 km^2 (2 x 1.5 km^2)

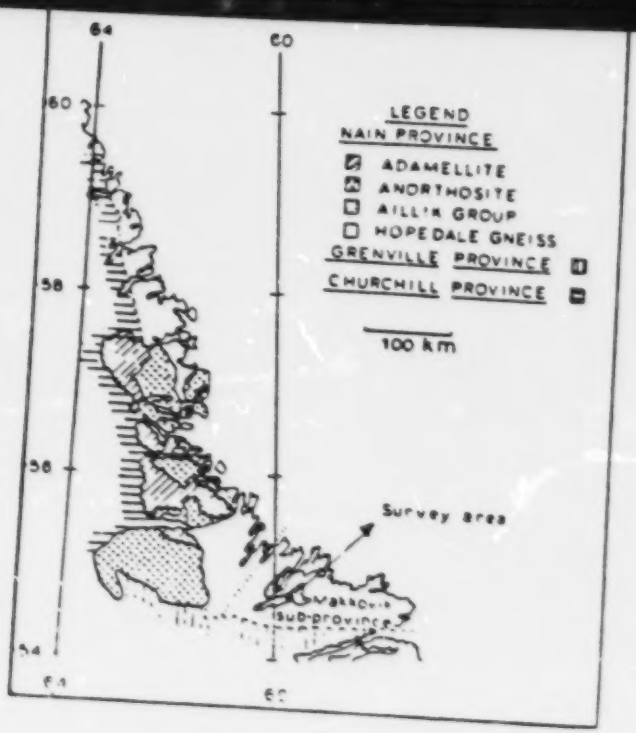


Figure 7-3 Site Location
Michelin, Kaipokok, Nfld.

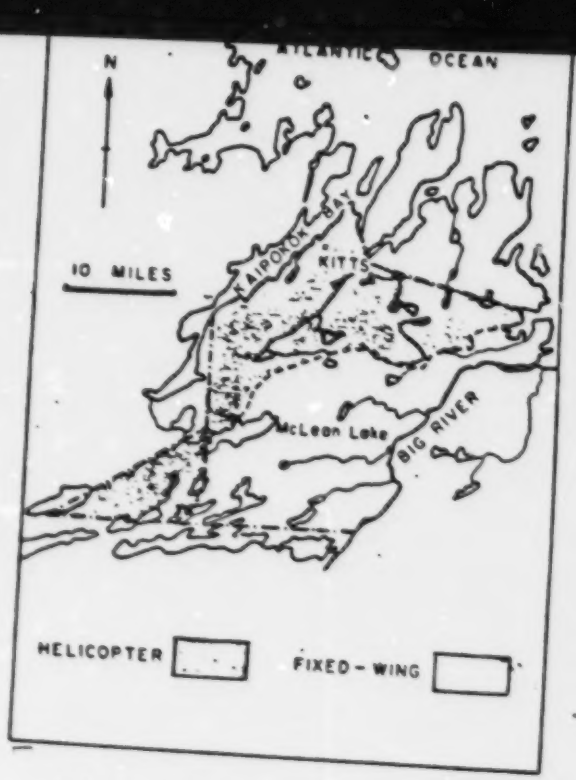
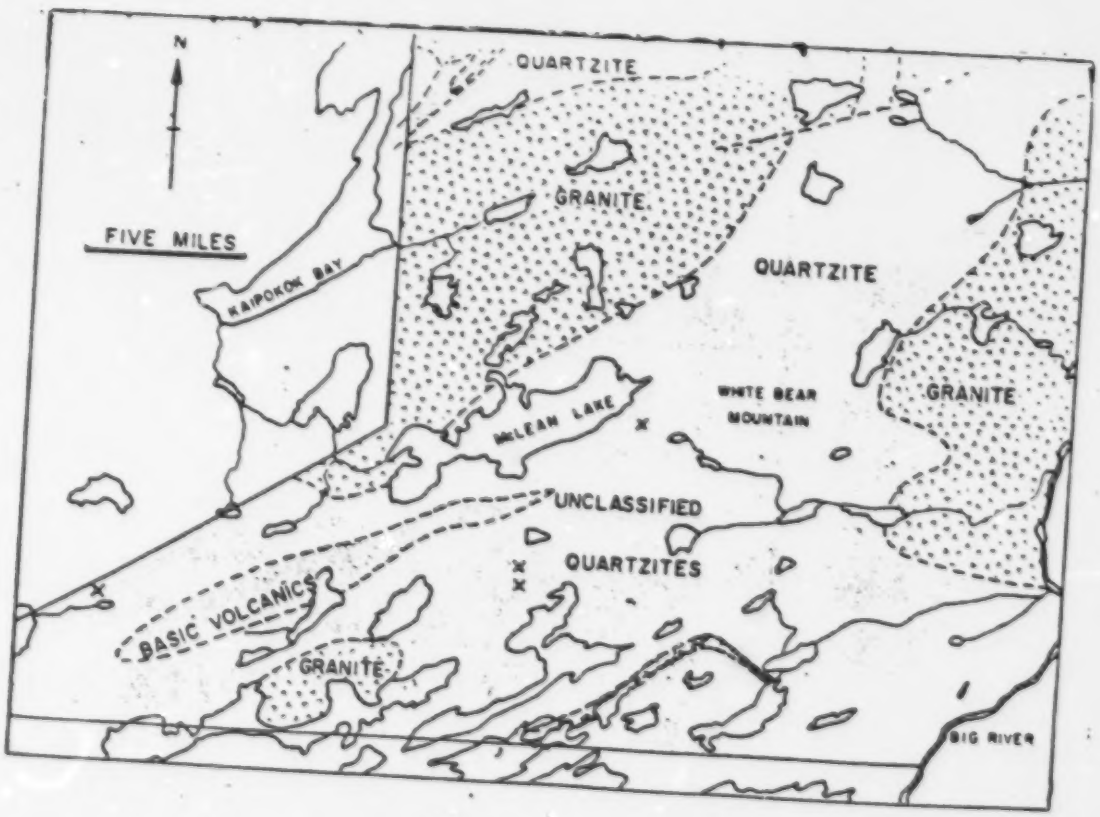


Figure 7-1
Site Location, Kaipokok,
Nfld.

Figure 7-2 Site Location, 15 km South of Kitts,
Kaipokok, Ndld



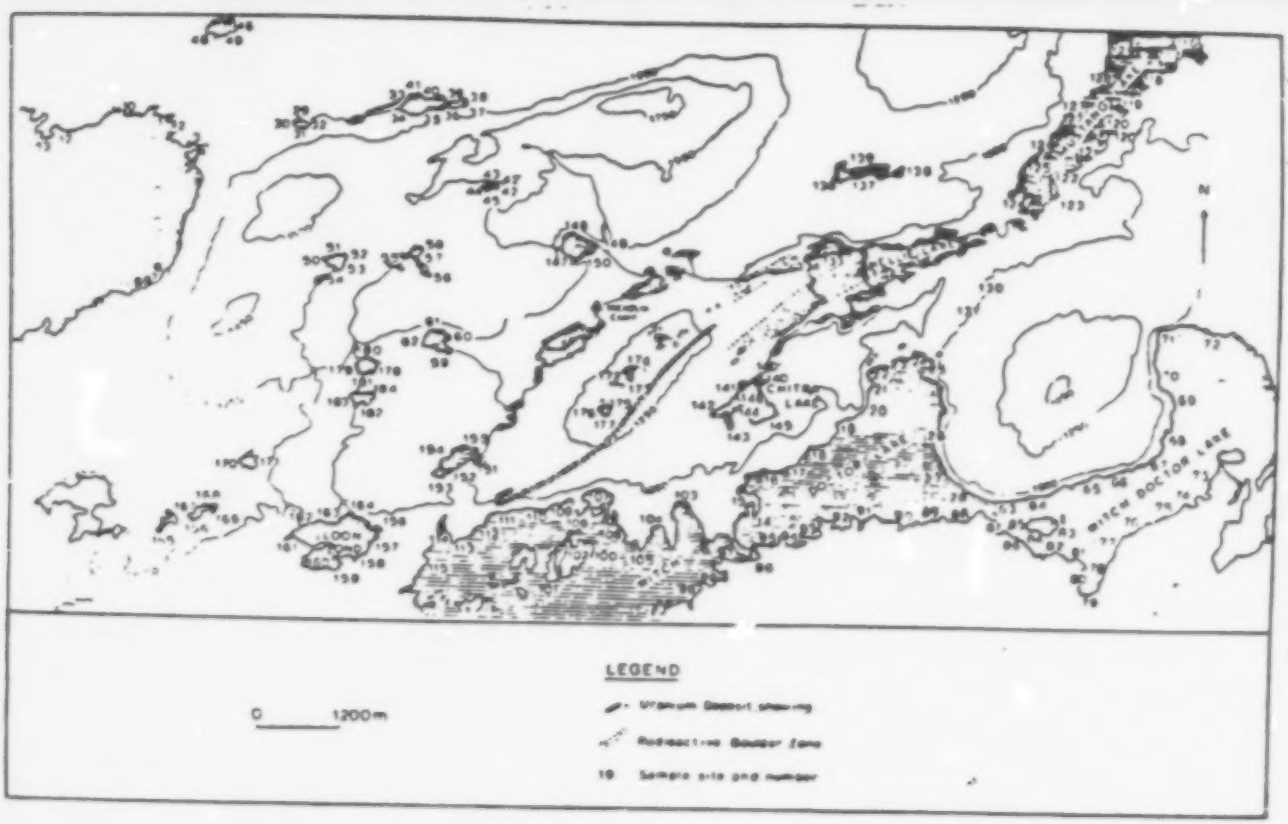
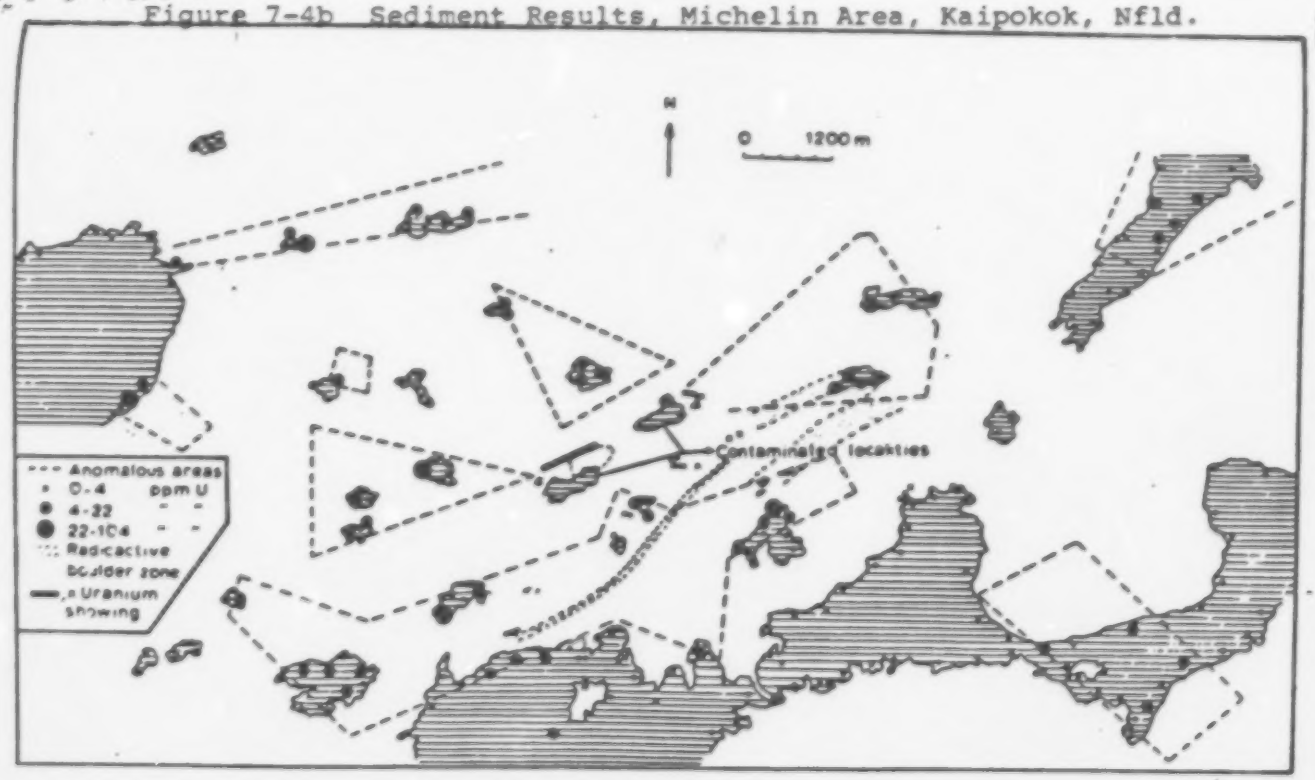
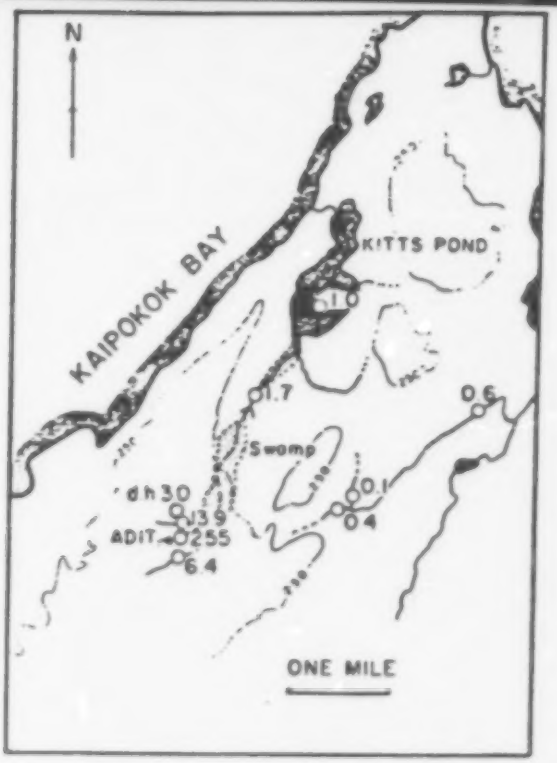


Figure 7-4a Location of Sediment Samples, Michelin Area, Kaipokok

Figure 7-4b Sediment Results, Michelin Area, Kaipokok, Nfld.

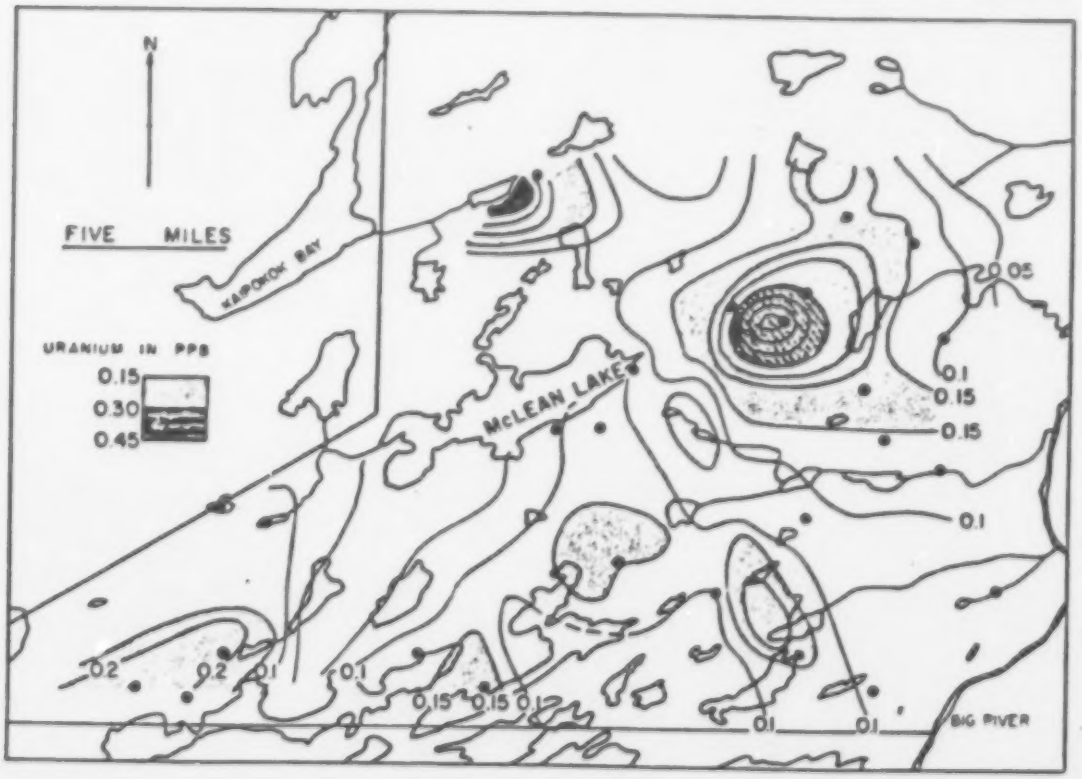




Uranium (in ppb) in water samples from the vicinity of the Kitts deposit.

Figure 7-5

Figure 7-6 Lake Water Results, 15 km S. of Kitts, Kaipokok



SITE 8
LINEAMENT LAKE, NORTHWEST TERRITORIES

References

Cameron, E.M., Durham, C.C. 1974. Geochemical studies in the Eastern part of the Slave Structural Province. GSC Paper 74-27, 22 pg.

A regional of 4600 km^2 delineated a uranium anomaly in lake sediments. The results of the lake sediment survey are shown in figure format.

Dyck, W., Camerson, E.M. 1975. Surface lake water uranium-radon survey of the Lineament Lake area, District of Mackenzie. GSC Paper 75-1A pp. 209-212.

The results of a lake survey of 500 km^2 within the lake sediment anomaly is provided in a basemap. The results are not discussed in detail. The results of an airborne gamma ray survey are also shown.

Site Description

This study has been included because of the geology and because no known uranium mineralization is reported for this area.

This area is situated about 100 km south-southeast of Friday Lake. It is covered by massive granitic rocks comprised mainly of biotite granites and quartz monzonite of Archean age.

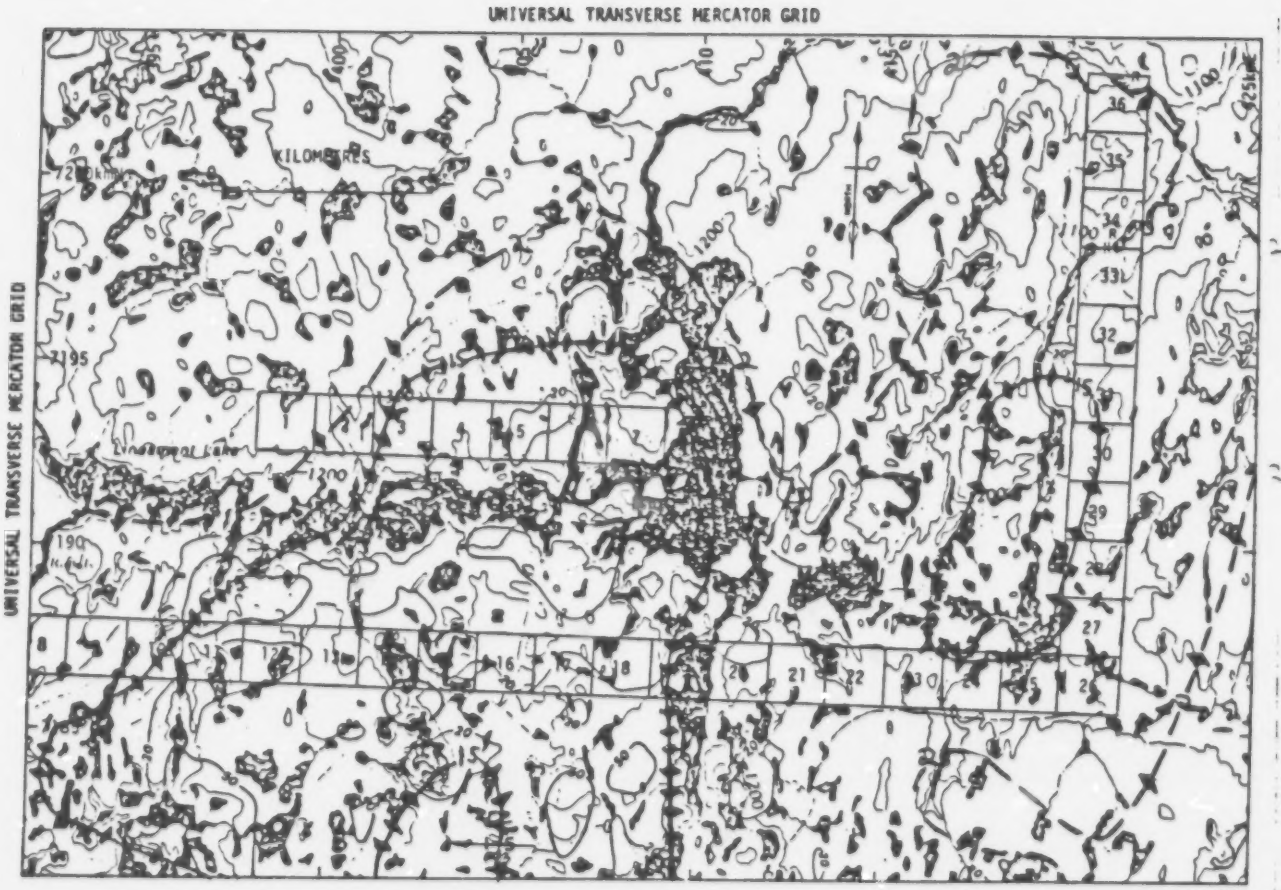
Description of Uranium Anomalies

The information on the anomalies is provided in Table 8-1. Figure 8-1 shows the sediment anomaly and some airborne gamma ray spectrometer results.

TABLE 8-1 URANIUM CONCENTRATIONS AND ANOMALIES AT LINEAMENT LAKE, NORTHWEST TERRITORIES

Media	Concentrations	Anomalies
ROCK: granites and monzonites, no uranium mineralization		
1) chemical analysis	n = 8 3.2 - 5.3 ppm	no anomaly, values are 2 times granites outside lake sediment anomaly
2) airborne gamma ray spectrometry	1 value per 1.6 total of 36 squares total area 57.6 km^2	b.g. 20 - 30 counts peaks 85, 97 counts
LAKE SEDIMENTS: nearshore samples, study area 4600 km^2	n = 1349 ?(<2) - 70 ppm geo. mean 0.7 ppm arith. mean 1.3 ppm	a) anomaly defined by 2 ppm contour, 770 km^2 (19 x 40 km^2) b) anomaly defined by 15 ppm contour, 3 areas total 230 km^2 - 189 km^2 (0.5 x 21 x 18 km^2) - 25.6 ^{2} (3.2 x 8 km^2) - 15.4 ^{2} (2.4 x 6.4 km^2)

LAKE WATERS:		
sampled 2/3 of lake sediment anomaly (approx. 500 km^2)	n = 307 n = 257 (1 sample/2.6 km^2) mean = 0.2 ppb range = 0.0 - 1.0 ppb n = 50 (more detailed) mean = 0.3 ppb range = 0.0 -1.9 ppb	background = 0.2ppb if anomalous 0.4ppb total area = 16km^2; location displaced to south of lake sediment anomaly



AIRBORNE GAMMA RAY SPECTROMETER COUNTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
346	389	387	383	453	474	465	488	511	484	520	570	516	512	473	637	552	527
38	49	43	64	48	60	50	46	36	59	74	85	97	75	73	73	58	49
75	72	43	52	80	105	174	120	134	120	137	173	246	274	193	182	163	186

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
712	643	665	665	676	578	408	410	541	447	378	365	435	401	342	382	544	454
49	21	38	24	21	15	28	24	50	33	8	33	30	41	15	51	58	51
127	136	115	114	165	113	53	58	77	80	47	35	32	71	18	72	145	114

Uranium in ppm in lake sediments (Map 9-1972 (Sheet 3)) 15

Study area 5

Figure 8-1 Site Location, Sediment Anomaly, Airborne Results Lineament Lake, NWT

SITE 9
MIDWEST DEPOSIT, ATHABASCA BASIN, SASKATCHEWAN

References

Dunn, C.E. 1982. Detailed biogeochemistry studies for uranium in NEA/IAEA Athabasca test area. In: Uranium exploration in Athabasca Basin, GSC Paper 82-11, Ed. E.M. Camerson, pp. 259-271.

Various plant samples are collected from a regional and local survey. No basemap is provided with the results of the local survey so no anonaly was outlined.

Dyck, W. 1982. Geochemical studies of lakes near Midwest and McClean uranium deposits. In: Uranium exploration in Athabasca Basin, GSC Paper 82-11, Ed. E.M. Cameron, pp. 243-257.

Semidetailed and detailed lake sediment and water samples were analyzed.

Dyck, W., Camerson, E.M., Richardson, K.A. 1982. Radon, gamma-ray spectrometer, and trace element investigations of soils at Midwest and McClean uranium deposits. In: Uranium exploration in Athabasca Basin, GSC Paper 82-11, Ed. E.M. Cameron, pp. 215-241.

Soils collected from baselines located over the south end of South McMahon Lake were analyzed by numerous methods including geochemical uranium.

Simpson, M.A. Sopuck, V.J. 1982. Till geochemistry near the Midwest uranium deposit. In: Uranium exploration in Athabasca Basin, GSC Paper 82-11, Ed. E.M. Cameron, pp. 207-214.

Basal till samples were collected from the southern end of South McMahon Lake and analyzed for uranium.

Sopuck, V.J., de Carle, A., Wray, E.M. 1983. Application of lithogeochemistry to the search for unconformity-type uranium deposits in the Athabasca Basin. In: Uranium exploration in Athabasca Basin, GSC Paper 82-11, Ed. E.M. Cameron, pp. 191-205.

This reference provides data on the Midwest ore deposit.

Site Description

The Midwest deposit is located in Northern Saskatchewan in the Athabasca Basin (Figure 9-1). The deposit is covered by up to 200 m of Athabasca sandstone. It is an unconformity-type deposit as it is situated at the sub-Athabasca unconformity overlying graphite-rich metapelitic basement rocks and it is closely related to faulting. A silty medium sand till ranges in thickness from 1 to 2 m (south of the deposit). Soil profiles are poorly developed.

Eskers, drumlins freeze-thaw boulder fields and peat deposits are also present throughout the area. Till thicknesses in the vicinity of the deposit are thin (i.e. 5 m) (Figure 9-2).

Uranium Anomaly Descriptions

A summary of the uranium concentrations in various environments is presented in Table 9-1. The extent of any anomalies is provided is this table. Information is available for the following environments: rock, lake sediments, lake waters, overburden/soils, and plants. Generally the data is very site specific. All of the information was taken from GSC Paper 82-11.

Rock Anomalies:

The deposit encountered 200 m below ground surface, is a flattened elongate body extending over 900 m with an approximate width of 50 m (Figure 9-3). Uranium concentrations (>3 ppm) in the sandstone define a halo more than 200 m laterally across the deposit. The main ore minerals are pitchblende, coffinite, gersdorffite, rammelsbergite and niccolite.

Overburden/Soils Anomalies

Within the till overburden, a mineralized boulder train is present. The ore grade boulders are derived due to glacial erosion from the fractured, mineralized Athabasca sandstone underlying South McMahon Lake. The mineralized clasts form a band approximately 400 m wide and extend 1.3 km south to southwest from McMahon Lake to a wet bog and a lake (Figure 9-4). The mineralized clasts occur within and on top of the till unit. Basal till samples also show anomalous concentrations which extend at least 900 m southwest of McMahon Lake (Figure 9-5). Till samples collected below the lake indicate that the geochemical halo continues northeasterly for some 1800 m under the lake.

Shallow soil samples (i.e. 40 cm from ground surface) (see sampling grid Figure 9-3) did not detect the boulder trains nor the mineralized fracture zone south of South McMahon Lake.

Lake Sediment Anomalies:

Both semidetailed and detailed surveys were carried out in the vicinity of the deposit. The results of the semidetailed lake sediment survey are shown in Figure 9-6. Organic rich lake sediments have less erratic and greater contrasts between anomalous and background levels than lake waters. The author (Dyck, 1982) does not specify what are background or anomalous values. Based on estimating that anomalous values are greater than 4 ppm, most of the length of South McMahon Lake (4 km) is found to have anomalous sediments.

A detailed sampling of the anomalous areas of South McMahon Lake was undertaken (Figure 9-7). The locations of the baselines are shown in Figure 9-4. The sharp peak on line 124 is reported to be believed to be due to spillage of high grade ore from a drill core at this point. The 8 ppm or greater results roughly outlined the uranium mineralization.

Weathering of the mineralized boulders is reported as the likely source of the lake sediment and water anomalies of S. McMahon Lake under which the main ore zone lies.

Lake Water Anomalies:

The results of the semidetailed study are shown in Figure 9-8. The detailed water sampling of these lakes is outlined in (Figure 9-7). The locations of the baselines are shown in Figure 9-5. The sharp peak on line 124 is believed to be due to spillage of high grade ore from a drill core at this point. It was reported that modal uranium values in the waters drop slightly in going from the southern end of the lake, close to the boulder train, towards the northern end in the direction of drainage.

Plant Anomalies:

It was considered that biogeochemical data was inconclusive and that a more detailed study was required in order to discern a clear relationship with the mineralization. The potential difficulties of this were noted because of the fact that most of the deposit is under the lake.

TABLE 9-1
URANIUM CONCENTRATIONS AND ANOMALIES AT MIDWEST DEPOSIT, ATHABASCA BASIN, SASKATCHEWAN

Media	Concentrations	Anomalies
ROCK: 200 m below ground surface principal part of the deposit lies under South McMahon Lake	richest ore at southern end - up to 43% U over 9 m,	extends over 900m in length, width approx. average of 50 m
LAKE SEDIMENTS: 1) semidetailed sampling of 24 km^2 (8 x 3 km^2)	n = 48 range 0.9 - 13.2 ppm	estim. b.g. 1-2 ppm, anomalies >4 pmm, most of S. McMahon L. is anomalous 2 km^2 (0.5 x 4 km^2)
2) detailed sampling of anomalous areas from semi-detailed sampling over South McMahon Lake, 5 km^2 (1 x approx. 5 km^2)	n = 66 mean = 6.7 ppm range = 1.8 - 12.0 ppm	results confirmed the semidetailed study
LAKE WATERS: 1) semidetailed sampling of 24 km^2 (8 x 3 km^2)	n = 36 mean = 0.07 ppb range = 0.05 - 0.48 ppb	estim. b.g. 0.1 ppb, anomalies >0.2 ppb, south end of S. McMahon L. is anomalous 0.5km^2 (1 x 0.5km^2)
2) detailed sampling of anomalous areas from semi-detailed sampling over South McMahon Lake, 5 km^2 (1 x approx. 5 km^2)	n = 44 mean = 0.18 ppb range = 0.05 - 3.0 ppb	

OVERBURDEN/SOILS:		
1) boulder train south of deposit,	ore grade boulders	boulder train 400 m wide and extends SE from S. McMahon lake for 1.3 km
2) basal till samples collected near and under the southern shore of S. McMahon Lake, 506 samples collected from mineralized boulder train, study area 3 km^2 (0.9 x 3.2 km^2), samples collected at base of till, <250 mesh samples analyzed	n = 361 mid point 19 ppm range 0 to 38 ppm	1 anomaly (= > 4 ppm) area = 90 x 2600 m^2 = 0.2 km^2
3) soil horizon Ah samples near southern shore of S. McMahon Lake, area 1.9 km^2 (1.2 x 1.6 km^2), from a depth of 40 cm	n = 317 mean = 1.6 ppm range = 0.4 - 6.3 ppm	boulder train not detected, mineralized fracture zone south of lake not detected

PLANTS: 1) regional study, study area 1350 km^2 (45 x 30 km^2), collected black spruce	n = 1000	plant data in area of Midwest deposit 50 - 100 ppm
2) samples collected at 150 m intervals over deposit, no basemap provided, no study area shown a) spruce trunks	a) 300 sites over 95% <0.2ppm (d.l.) max. 1.1 ppm ash (contaminated ?)	no anomalies outlined
b) labrador tea stems	b) n = ? 8 - 46 ppm ash	
c) labrador tea leaves	c) n = ? 4 - 39 ppm ash	
d) spruce twigs	d) 69 sites 20 - 139 ppm ash	

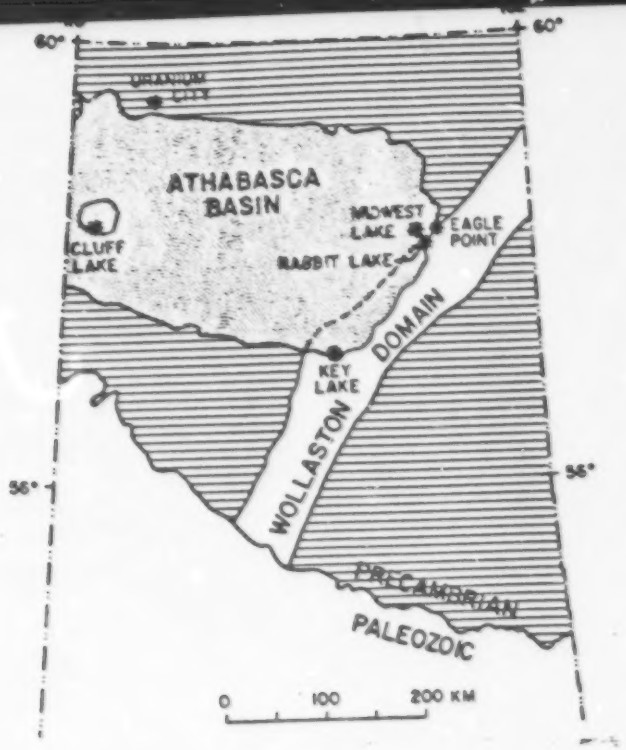


Figure 9-1 Site Location, Midwest, Saskatchewan

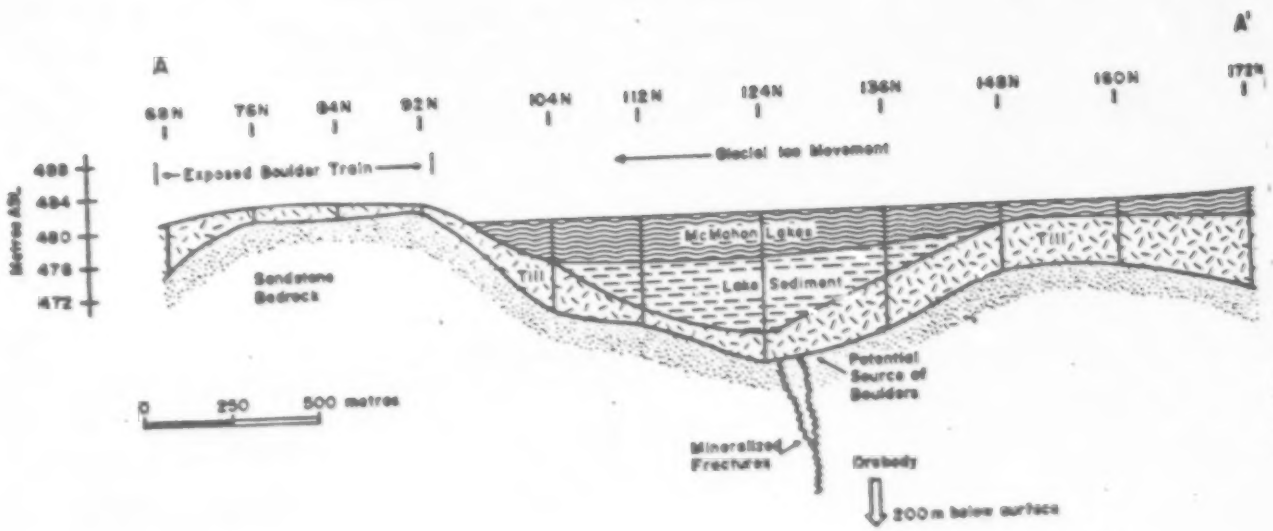


Figure 9-2 Cross Section, Midwest, Saskatchewan

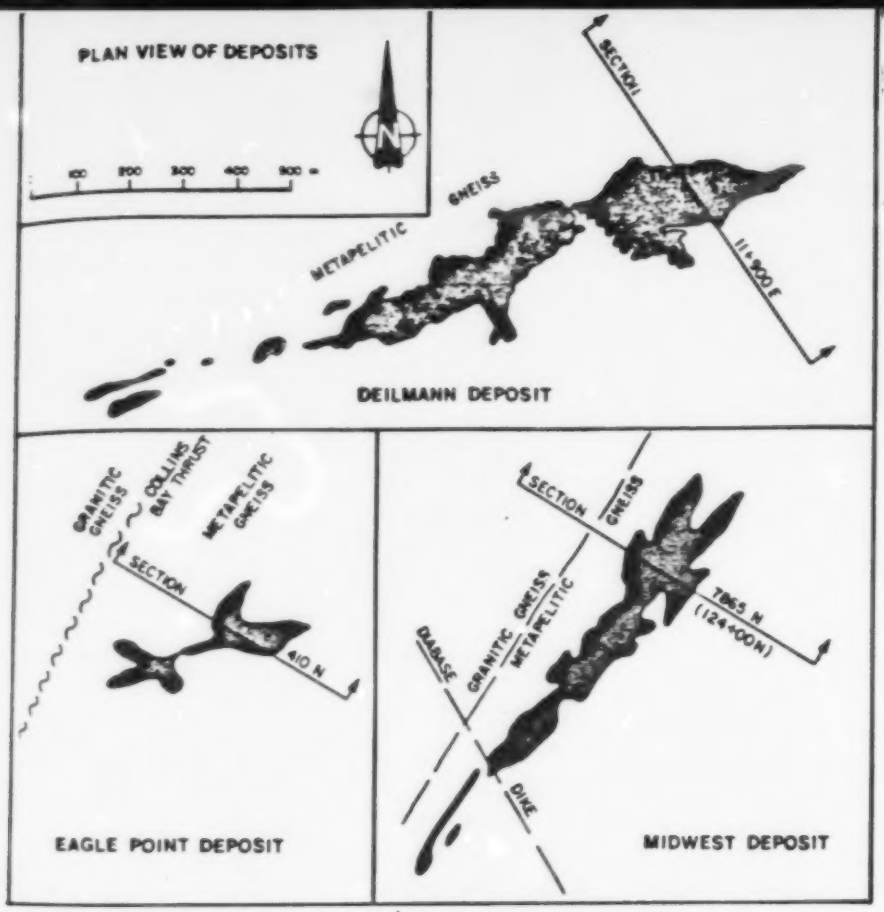


Figure 9-3
Orebody
Midwest
Sask.

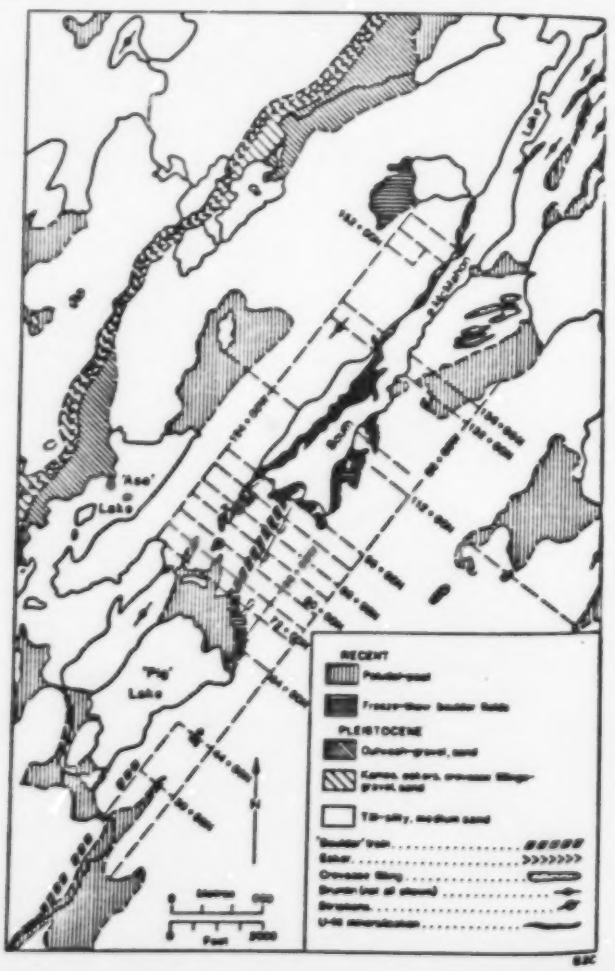


Figure 9-4
Location of
Mineralized
Boulder Trains
and Cross Section
Lines, Midwest,
Sask.

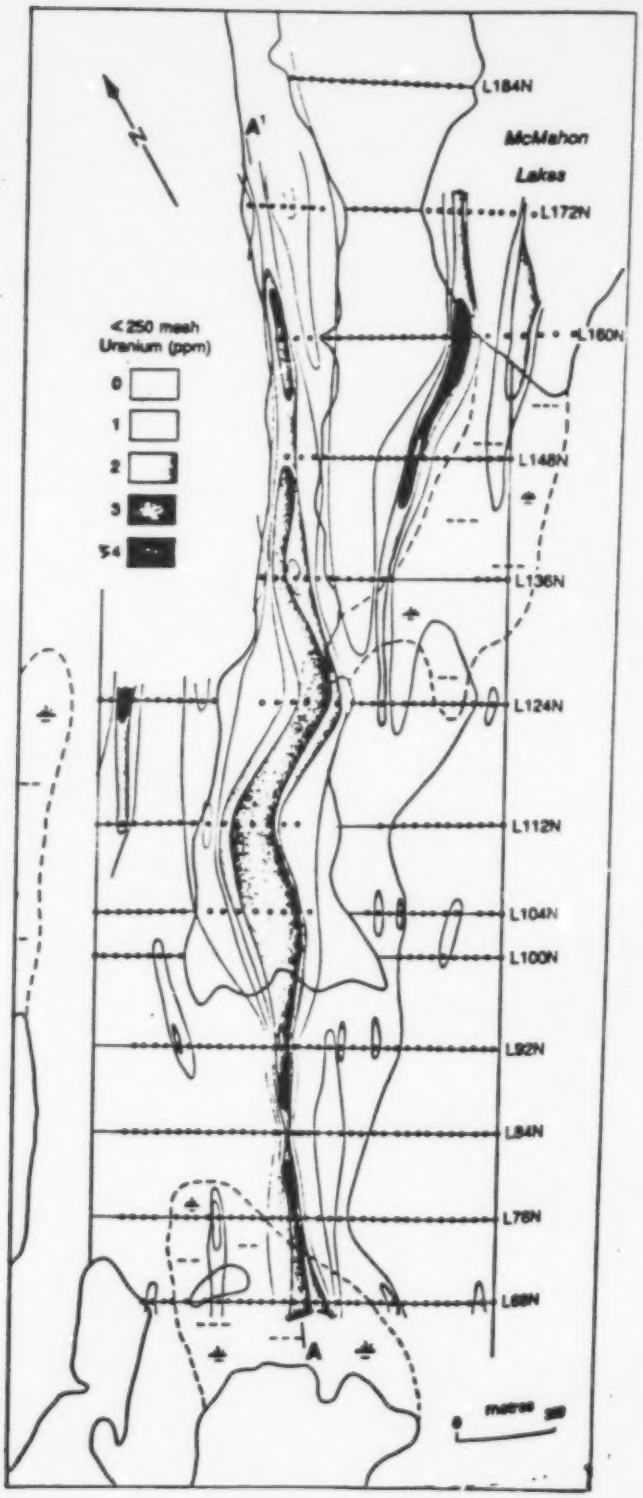


Figure 9-5
Basal Till
Results,
Midwest, Sask

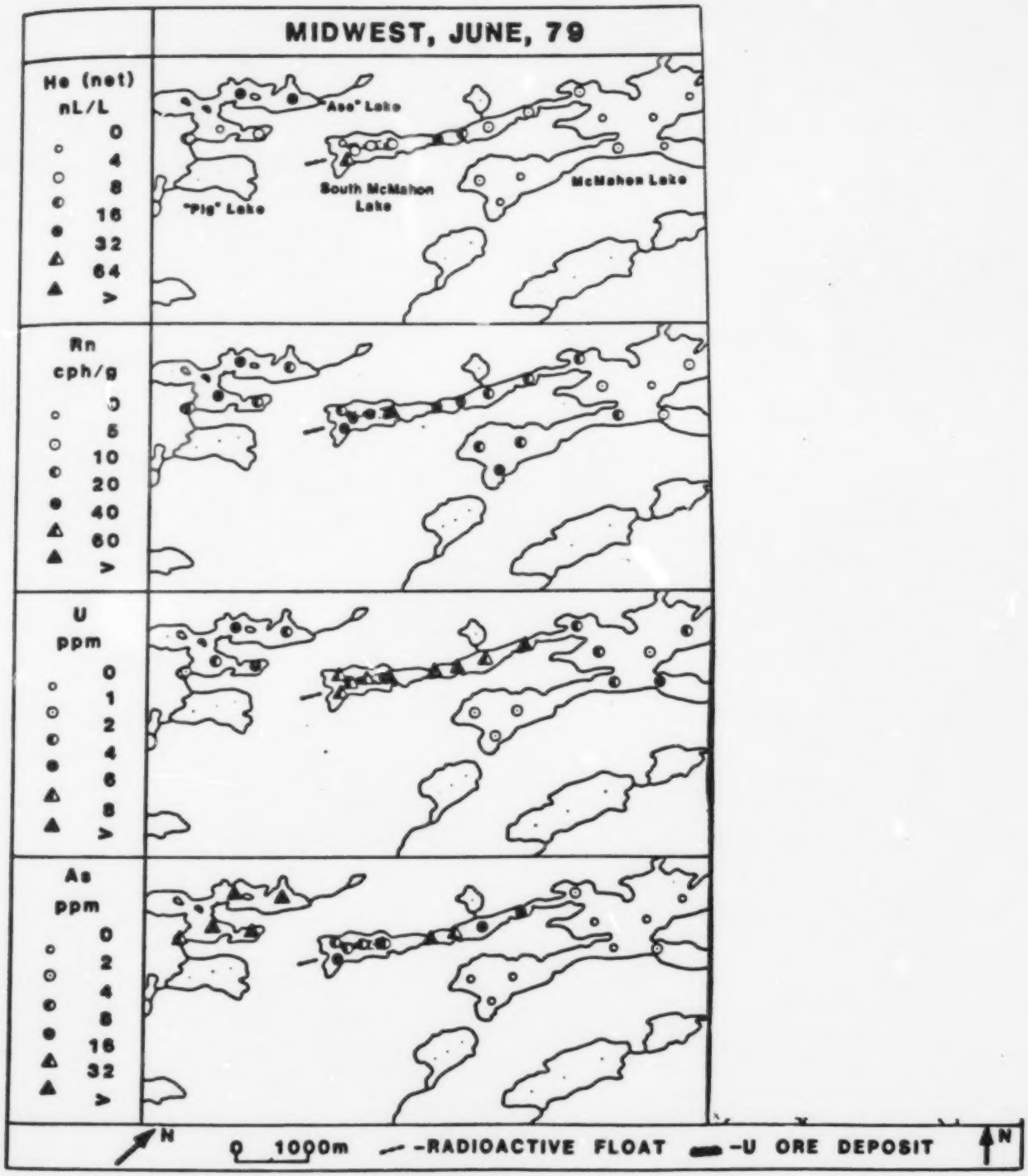


Figure 9-6 Semidetailed Lake Sediment Survey, Midwest, Sask.

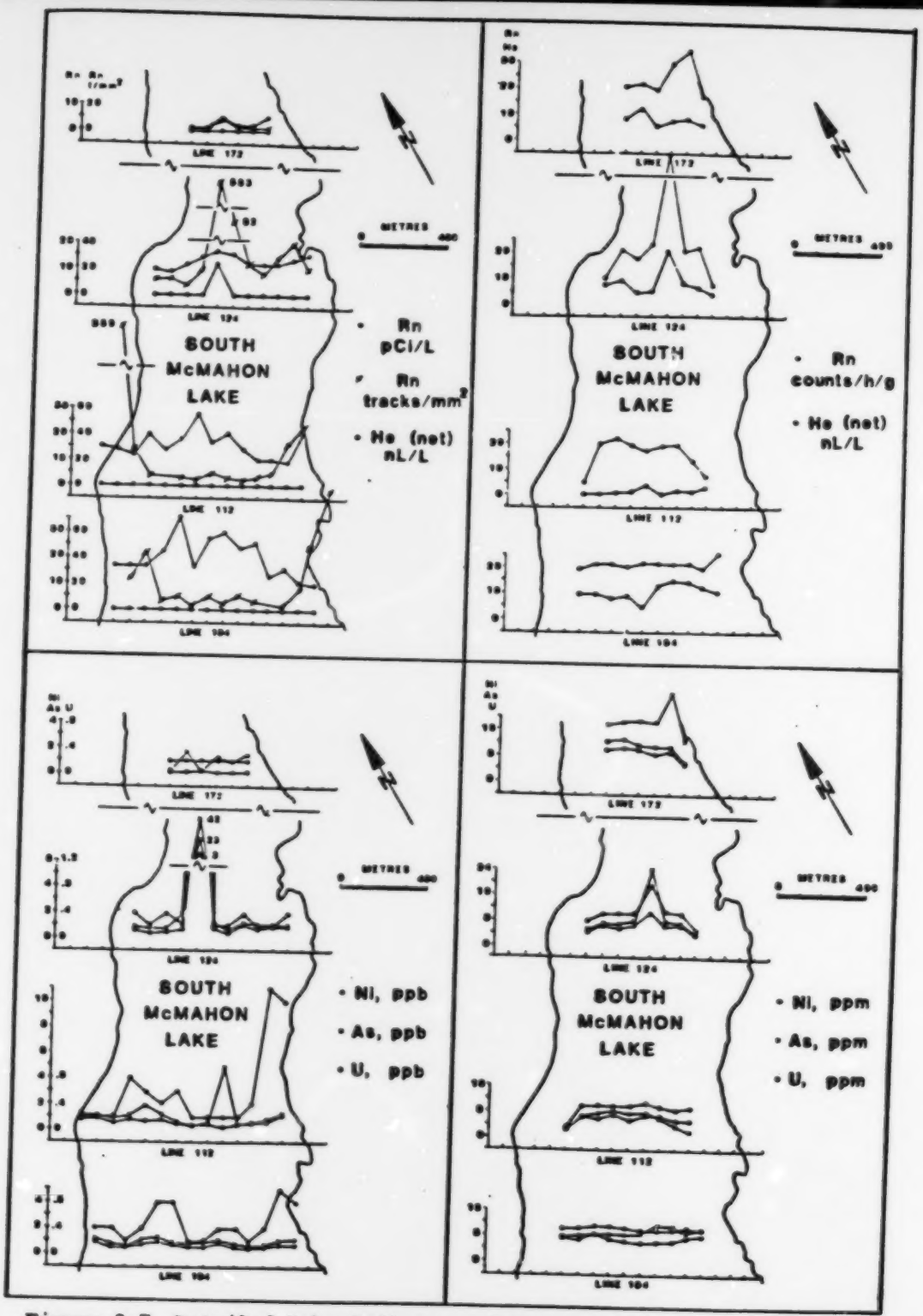


Figure 9-7 Detailed Lake Sediment and Water Results, Midwest, Sask.

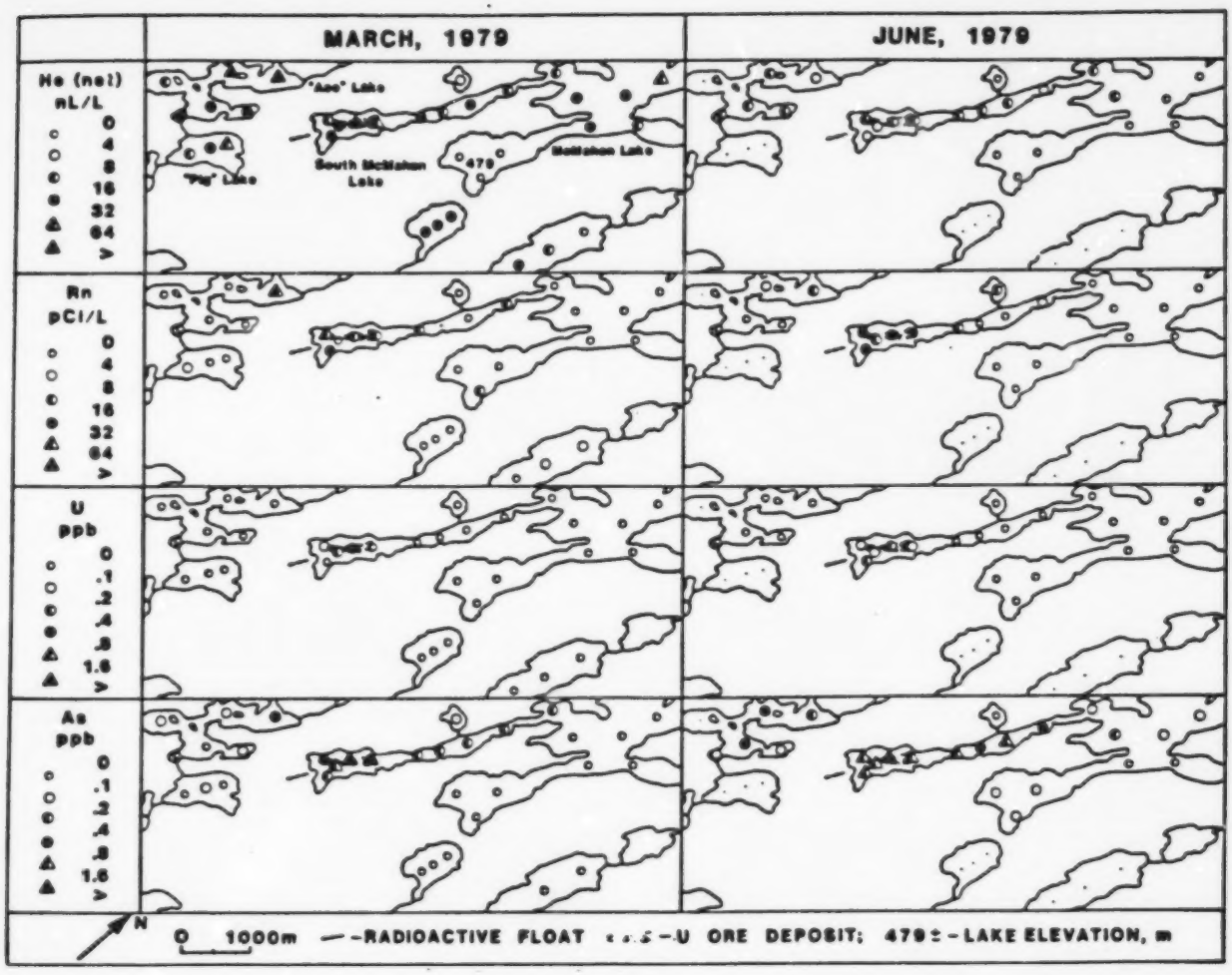


Figure 9-8 Semidetailed Lake Water Results, Midwest, Sask.

References

Card, J.W. 1978. Spontaneous deposition of radon products from air. M.Sc. thesis, Carleton University, Ottawa, 108 pg. This paper was used for the uranium results in soil collected from the baseline.

Charbonneau, R.W. Jonasson, Ford, K.L. 1975. Cu-U mineralization in the March Formation Paleozoic rocks of the Ottawa-St. Lawrence Lowlands. GSC Paper 75-1, Part A, pp.229-233.

This paper provides general information on the geology, mineralogy and geochemistry of the uranium occurrence. The work of Ford (1975) on uranium in soils is taken from this paper.

Dyck, W. 1980. Uranium, radon, helium and other trace elements and gases in well waters of parts of the St. Lawrence Lowlands, (Ottawa Region) Canada. Journal of Geochemical Exploration 13: 27-39.

A regional well water survey was undertaken in this study. These results only provide an estimate of the size of the anomaly and of the maximum concentrations.

Ford, K.L. 1975. Petrography, geochemistry and geophysics of a uranium-copper occurrence, South March, Ontario, B.Sc. thesis, Carleton Univversity, Ottawa, 62 pg.

Uranium concentrations in soils collected from a grid over the anomaly are reported in this thesis.

Gordon, S.L. 1986. The environmental geochemistry of total uranium and ^{226}Ra at the South March uranium occurrence, Ontario, M.Sc. thesis, Carleton University, Ottawa, 131 pg.

The uranium concentrations in plants collected from a baseline are prsented in this paper.

Grasty, R.L., Charbonneau, B.W., Steacy, H.R. 1973. A uranium occurrence in Paleozoic rocks west of Ottawa. GSC Paper 73-1A, pp. 286-289.

The discovery of the South March air-borne gamma-ray anomaly is described in this reference. Details on the mineralization are provided.

Jonasson, I.R., Dyck, W. 1974. Some studies of geochemical dispersion about a small uranium showing, March Township, Ontario. GSC Paper 74-1B, pp. 61-63.

Uranium in stream sediments in the vicinity of the occurrence are reported in this study.

Site Description

The South March uranium occurrence is found in the Ottawa-St. Lawrence Lowlands, approximately 20 kilometres west of Ottawa, Ontario (Figure 10-1). At South March, Palaeozoic sedimentary rocks rest unconformably on Precambrian basement rocks. The study area occurs within the Mixed Forest vegetation zone where evergreens and deciduous species are equally prominent. The soils in the area are thin (less than 2 m), sandy loams or loamy sands. The site is fairly flat and the regional trend of surface flow is to the northeast, i.e. towards the Ottawa River. A few intermittent ponds are present.

The South March uranium occurrence was discovered by an airborne gamma ray spectrometer survey. The airborne anomaly was approximately 0.09 square kilometres. The mineralization seems to be associated with the sandy dolomites of the March Formation. Carbonaceous material in these rocks are radioactive.

Uranium Anomaly Descriptions

Information is available on the concentrations uranium in rocks, streams sediments, groundwater, soils and plants. The data for the stream sediments and groundwater are taken from studies that were more regional than for the studies for the rocks, soils and plants. The information is summarized in Table 10-1.

Rock Anomalies:

The mineralization in the rocks seems to occur in two 1 m thick sandy dolomite horizons. As indicated by shallow drilling, the two horizons are 3 metres apart and inclined. As surface outcrops, they are approximately 200 metres apart. An outline of the anomaly based on total counts >100 uR/hr is shown in Figure 10-2.

Stream Sediments Anomalies:

Refer to Table 10-1.

Groundwater Anomalies:

Refer to Table 10-1. Figure 10-1 shows the results of the regional survey of well waters.

Soil Anomalies:

Soil results delineate the mineralized horizons in the sandy dolomite. This is shown in Figure 10-3 from a sampling of a grid at the study area. Soil samples from a baseline also outline the two mineralized sandy dolomite horizons (Figure 10-3).

Plant Anomalies:

The plant concentrations for this area were generally low (maximum of 0.18 ug/g ash). As shown in Figure 10-4 there was a general correspondence of plant concentrations with soil concentrations.

TABLE 10-1 URANIUM CONCENTRATIONS AND ANOMALIES AT SOUTH MARCH, ONTARIO

Media	Concentrations	Anomalies
ROCK/SURFACE: airborne gamma ray spectrometry, thucolite in sandy dolomite	surface radioactivity 10 - 50 x background, max. 175 ppm eU on frost heaved blocks	anomaly outlined to be 150 x 600 m^2 (0.09 km^2)
STREAM SEDIMENTS 115 survey in vicinity of occurrence:	n = approx. 50 range = 0 - 11.0 ppm	anomaly shown over occurrence, sample density too low to determine size, max. value at site
GROUNDWATER: regional study of 22,000 km^2	n = 130 mean = 1.4 ppb range = <0.2 - 73.0 ppb	anomaly shown over occurrence, sample density too low to determine size, max. value at site
SOILS: 1) sampled from grid, area 1.7 km^2	n = 371 max. value 110 ppm	b.g. 1.9 ppm anomalous approx 4ppm 0.25 km^2 (390x360 m^2)
2) sampled from baseline 883 m long	n = 34 max. value 60 ppm	two main peaks correspond to mineraliz. dolomite horizons

PLANTS: sampled from baseline 883 m long	n = 112 range = 0.01 - 0.18 ug/g ash	generally low values, see correspondence with soil values anomalous est. 0.05 ug/g ash

Figure 10-1
Site Location,
South March,
Ontario

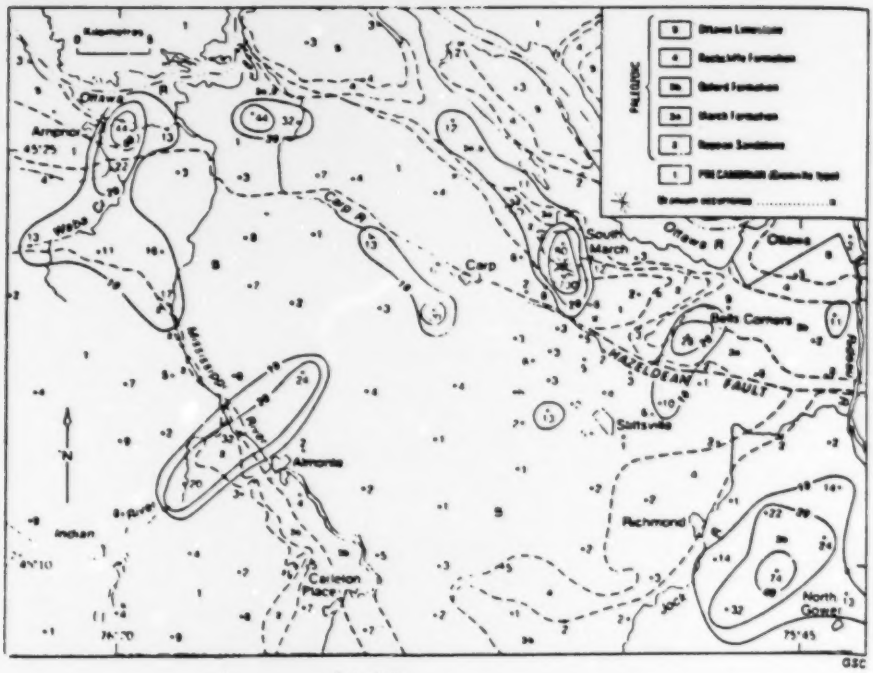
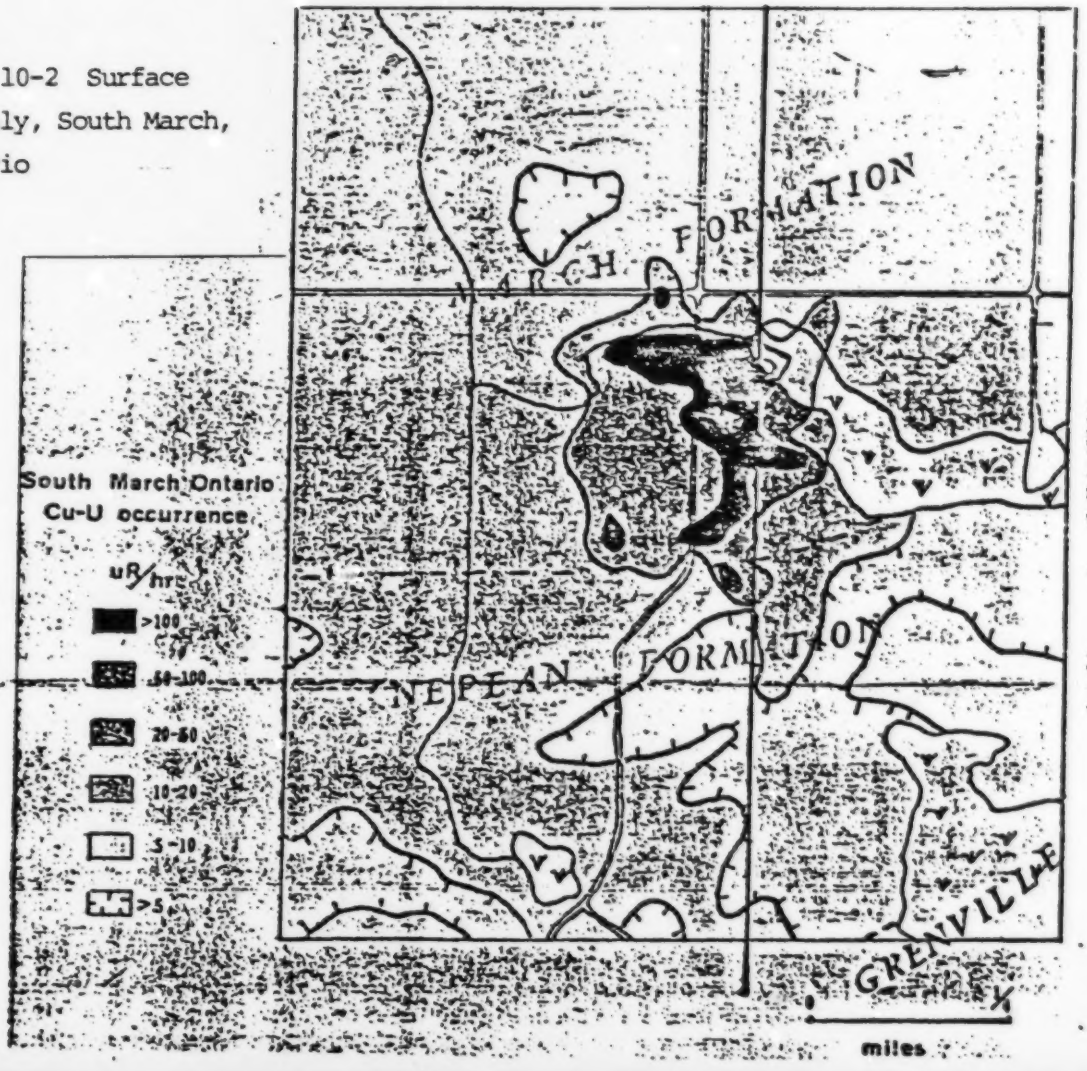
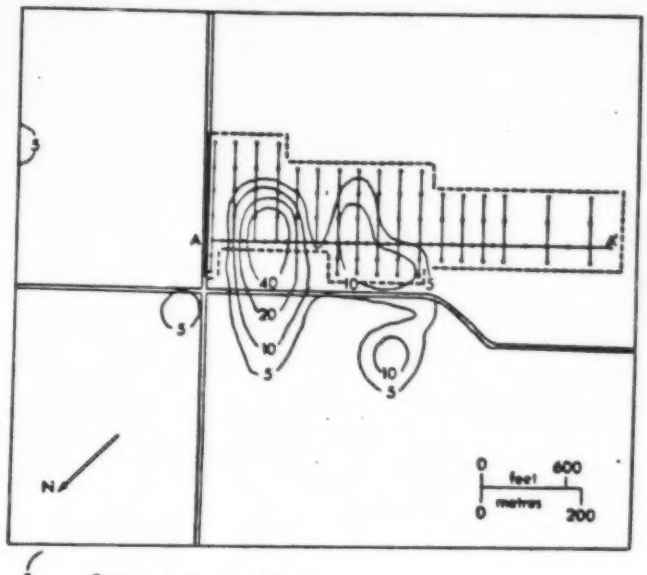


Figure 10-2 Surface
Anomaly, South March,
Ontario





5 Contours - ppm U in soils

• Survey stations

A - A' Baseline end-points

----- Boundary of area studied

Fig. 10-3 **Location of grid at the South March uranium-copper occurrence, with contour lines showing the distribution of radiometrically-determined uranium (adapted from Ford, 1975).**

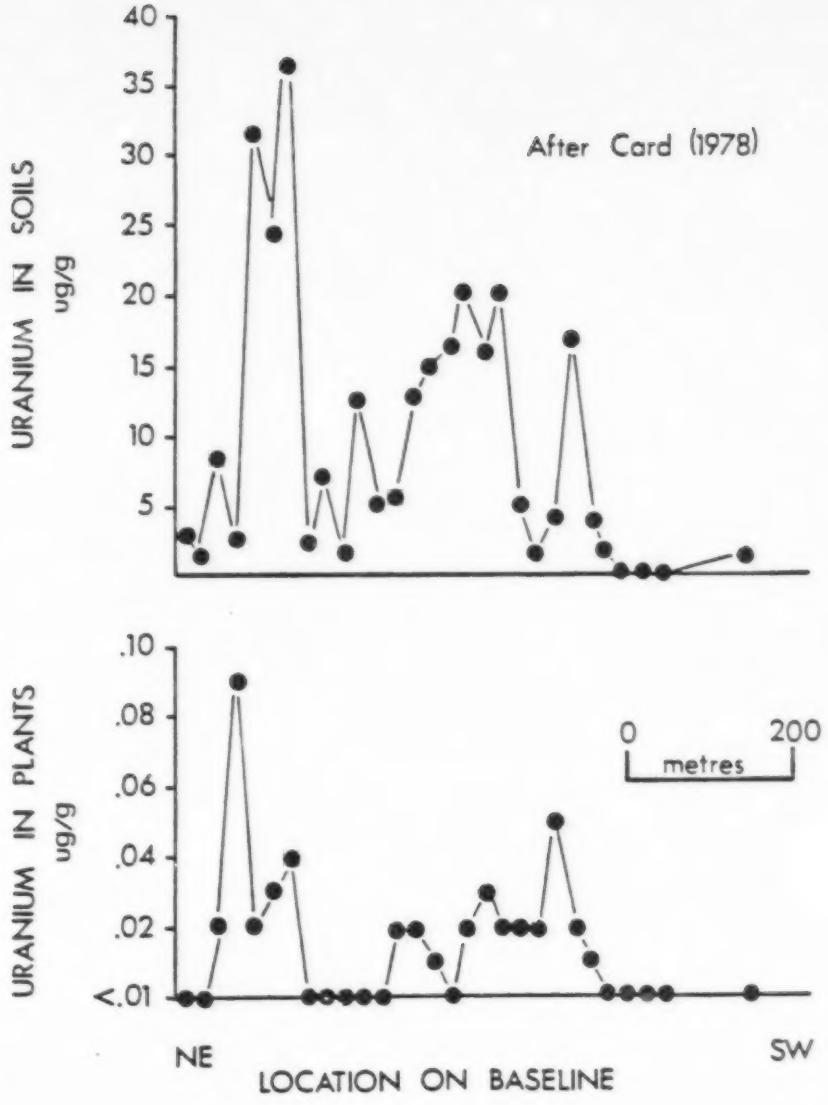


Figure 10-4

Total Uranium Baseline Profiles for South March Soils and Plants

SITE 11
KARELIA, FINLAND

References

Bjorklund, A.J. 1976. Use of Till in Geochemical Uranium Exploration. In: Proceedings on Exploration of Uranium Ore Deposits, Vienna, 1976, IAEA, pp. 297-309.

The general setting of the area is described. The results of the local lake sediment studies are compared with the location of uranium mineralization. The results of a regional lake sediment survey are also provided.

Bjorklund, A.J., Tenhola, M., Rosenberg, R. 1976. Regional Geochemical Uranium Prospecting In Finland. In: Proceedings on Exploration of Uranium Ore Deposits, Vienna, 1976, IAEA, pp. 283-295.

Based on anomalous lake sediment results, a survey of till in the same area is undertaken. The results are compared with a the location of known mineralization in bedrock.

Site Description

The location of the study area is provided in Figure 11-1. A regional study covered a 6000 square kilometre area. The topography in the study area is gently rolling, with a relief of 20 to 60 metres. There are many lakes in the area with extensive bogs in the eastern portion. The geology consists of Karelian rocks comprised of metasediments (schists and quartzites) resting on igneous and metamorphic basements rocks. The bedrock is mostly covered by till which in the western part is overlain by esker deposits. Peat covers the glacial drift in parts of the study area. In the valleys, the drift is 5 to 30 m thick and absent in the hilly areas. The Karelian rocks are only exposed occasionally.

At the time of the study no uranium ore of economic grade was known in Finland although several mineralized zones had been located. Mineralization is in metasediments of Karelian rocks. Small uraninite and pitchblende mineralizations are found mainly in quartzite. Uranium also occurs in metadiabase contacts and in small pitchblende veinlets within the metadiabases.

Uranium Anomaly Descriptions

There are three scales of studies for this area. One is a regional study of lake sediments over an area of 6000 square kilometres. These results are not discussed here. The results of individual lake and stream studies of uranium concentrations in sediments and waters are reviewed and summarized in Table 11-1. As well the results of uranium drift concentrations in Lake Paukkajajarvi are

provided.

Rock Anomalies

Refer to Table 11-1.

Lake/Stream Sediment Anomalies

The results of a regional study of lake sediments in a 6000 square kilometre area were used to pick three areas for detailed studies. The results of the regional survey are not discussed here although they are shown in Figure 11-1. The sampling of individual lake/stream sediments as shown in Figures 11-2 for Area-1 (Lake Paukkajajarvi), 11-3 for Area-2 (Lake Eronlampi and Lake Uskaljarvi) and 11-4 for Area-3 (Lake Kalkajarvi area) indicates that the lake/stream sediments are useful for locating broad zones of mineralization. Isolated mineralizations as in Figure 11-4 (Lake Kalkajarvi area) may not be indicated by sediment samplings.

Drift Anomalies

The results of the sampling of the drift (and bedrock samples) from the Paukkajanvaara area (Lake Paukkajajarvi) are shown in Figures 11-5 and 11-6. An anomaly is observed in areas of mineralization in bedrock but not for a fan of mineralized boulders. The highest uranium values in the drift are close to the mineralized bedrock and the content decrease rapidly upward. The author concludes from these results that the anomaly is hydromorphic in origin.

TABLE 11-1 URANIUM CONCENTRATIONS AND ANOMALIES AT KARELIA, FINLAND

Media	Concentrations	Anomalies
ROCK: at time of study no known uranium ore of economic grade, locations of known mineralization reported but no details on characteristics Area-1 = Lake Paukkajajarvi area Area-2 = Lake Eronlampi and Lake Uskaljarvi Area-3 = Lake Kalkajarvi area,		Area-1 numerous u. occurrences underlie and surround the lake. Area-2 surrounding bedrock contains weak mineralization. Area-3 anomal. uranium restricted to bedrock in southern end of lake.
LAKE/STREAM SEDIMENTS: small study of 3 lakes to examine the effects of the extent of mineralization Area-1 8 km^2 (4 x 2 km^2) Area-2 2.6 km^2 (1.6 x 1.6 km^2) Area-3 30 km^2 (6 x 5 km^2)	Area-1 n = 23, <8 - 2285ppm Area-2 n = 24, 8 - >64 ppm Area-3 n = 31, <8 - >64 ppm	Area-1 7 samples >100 ppm, 13 samples >64 - 100 ppm (3.5km) Area-2 5 samples >64 - 100 ppm (for L. Eronioampl only) Area-3 4 samples >64 - 100 ppm
DRIFT: sampled from Area-1, 2 km^2 (2 x 1km^2)	n = 37 <4 - 202 ppm	if anomalous = >10ppm 7 samples anomalous

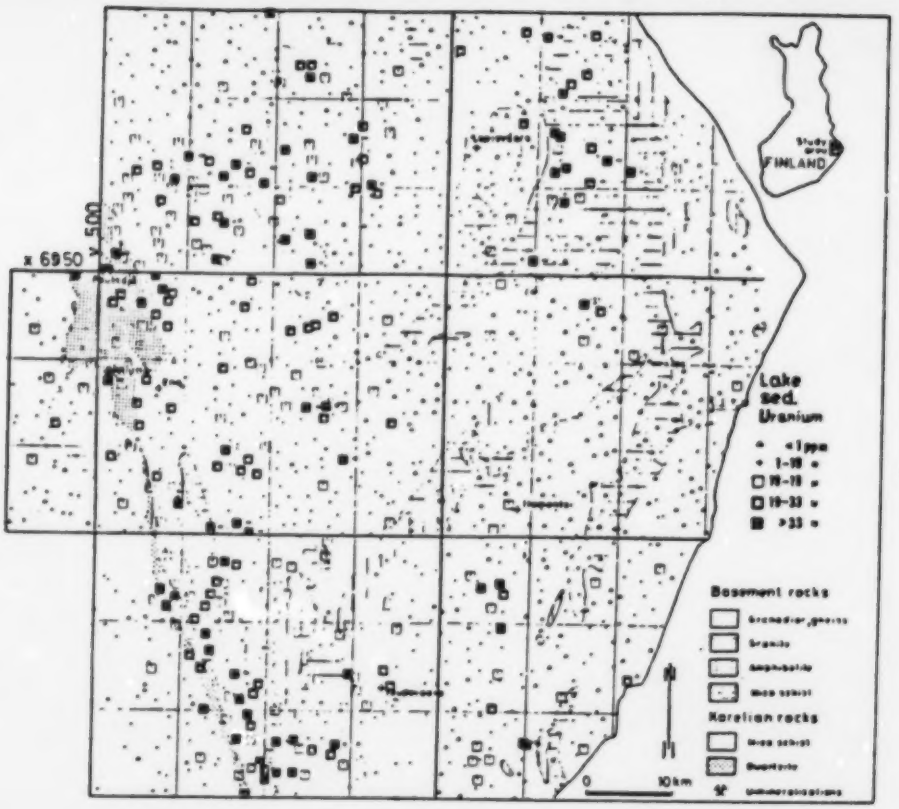


Figure 11-1 Site Location, Karelia, Finland

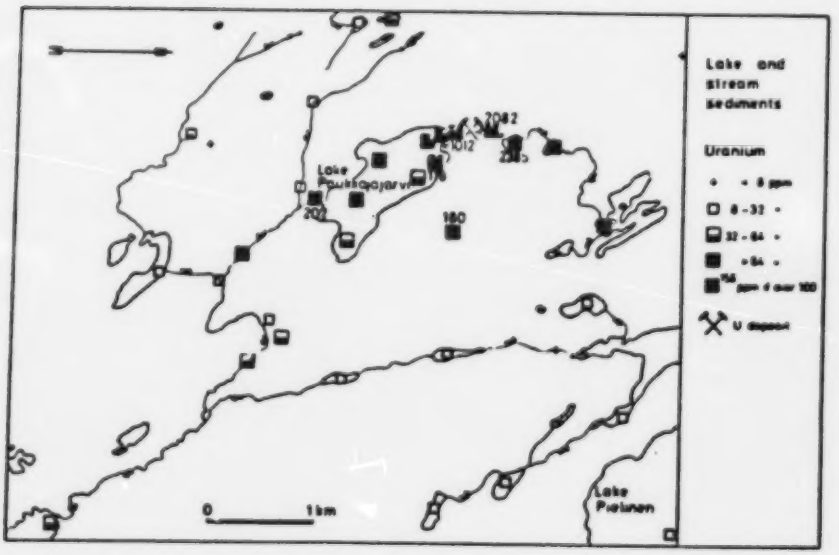


Figure 11-2 Lake and Stream Sediment Results, Lake Paukkajajarvi, Karelia, Finland

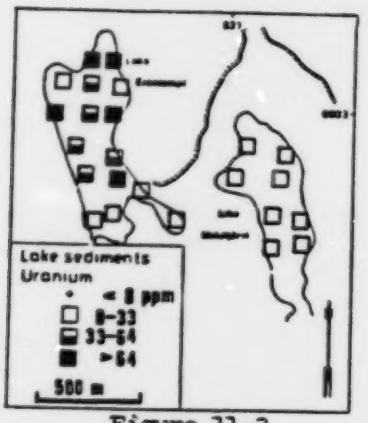


Figure 11-3

Uranium contents in ignited organic-rich sediments, lakes Eronlampi and Utkaljärvi, Karelia, Finland.

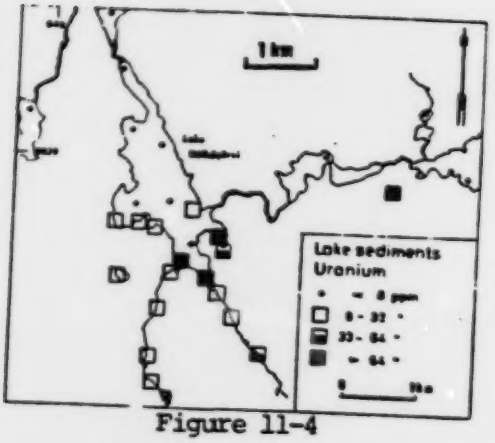


Figure 11-4

Uranium contents in ignited organic-rich lake and stream sediments, Kälkäjärvi, Karelia, Finland.

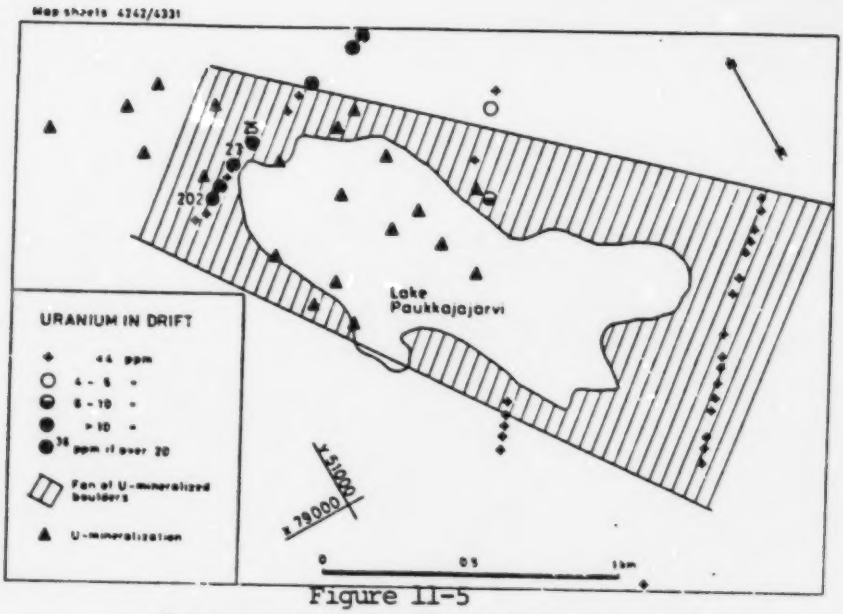


Figure 11-5

Uranium contents in glacial drift (−0.06 mm), Paukkajanvaara, Karelia, Finland.

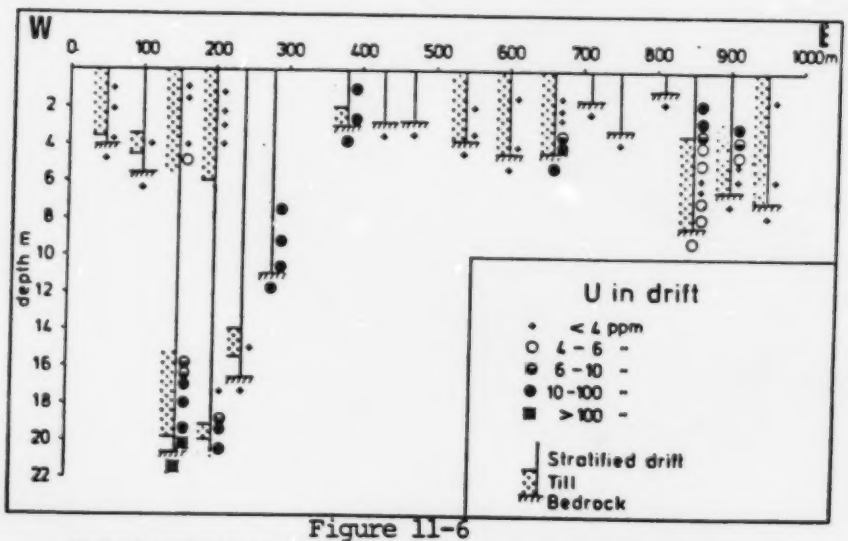


Figure 11-6

Uranium contents in the drift (−0.06 mm) profile of the northernmost sampling line in Fig.1, Paukkajanvaara, Karelia, Finland.

SITE 12
LOWER BULLER GORGE REGION, NEW ZEALAND

References

Beck, A.C., Reed, J.J., Willett, R.W. 1958. Uranium mineralization in the Hawks Craig Breccia of the Lower Buller Gorge Region, South Island, New Zealand. New Zealand Journal of Geology and Geophysics 1: 432-450.

The geology and the uranium mineralization are described.

Cohen, N.E., Brooks, R.R., Reevers, R.D. 1969. Pathfinders in geochemical prospecting for uranium in New Zealand. Economic Geology 64: 519-525.

The general setting of the study area is provided. The study measured the uranium concentrations in stream sediments.

Whitehead, N.E., Brooks, R.R. 1969a. Aquatic bryophytes as indicators of uranium mineralization. The Bryologist 72: 501-507.

Uranium was measured in aquatic byrophytes growing in streams in the area. Peat samples left in the streams were collected and analyzed for uranium and this data was used as a indication of the uranium content of the stream waters.

Whitehead, N.E., Brooks, R.R. 1969b. Radioecological observations on plants of the Lower Buller Gorge Region of New Zealand and their significance for biogeochemical prospecting. Journal of Applied Ecology 6: 301-310.

Further information on the physiography of the area was provided in this reference. Plants and soil samples were analyzed for uranium. There is no sample location map.

Wodzicki, A. 1959. Geochemical prospecting for uranium in the Lower Buller Gorge, New Zealand. New Zealand Journal of Geology and Geophysics 2: 602-612.

Surface water samples collected from creeks draining various rocks types were analyzed for uranium.

Site Description

The study area is located in the Lower Buller Gorge region of the South Island of New Zealand approximately 25 kilometres east of the township of Westport. The site is approximately 16 square kilometres (4700 by 3400 metres). The location of the site is shown in Figure 12-1. The data available on the site is summarized in Table 12-1. The majority of the data is for uranium concentrations in surface waters, creek sediments and plants

(bryophytes) growing in the streams .

The area receives abundant rainfall with a maximum of 500 cm/yr. The creeks are short and their profiles are steep. Several rivers run through the area, the major one being the Buller River. The relief varies between 600 to 1200 m. The steepness of the country precludes the accumulation of weathered material except at the foot of the bluff and in river valleys. Generally the weathering of the rocks is reported to extend only a short distance below the surface. The soils in the more stable parts of the terrain are classified as moderately weathered, podzolized, yellow-brown soils. The thicknesses of these soils are not reported however, it is mentioned that 250 g of soil can be collected from the B horizon. The area is heavily forested with a dense beech and podocarp forest which is reported to be typical for that part of New Zealand.

Uranium deposits are present as mineralized horizons in rocks of a formation called the Hawkes Craig Breccia. The Hawkes Crag Breccia is the surficial bedrock unit in the study area and is a sedimentary formation comprised of three facies. The formation dips to the southwest at angles of up to 40 degrees into a major fault at the Ohika-iti River, which forms the western boundary of the study area. The bedded uraniferous deposits are restricted to a clastic arkose sediment subunit labelled the Tiroroa facies. This facies is reported to mainly granitic-derived. No known uranium mineralization is reported in the other facies of the Hawks Craig Breccia or in the Ohika Beds which unconformably underlies the breccia. Weak radioactivity or in some places, weak mineralization have been observed in the basement rocks which are encountered below an unconformity beneath the Ohika Beds. A geology map of the study area is provided as Figure 12-1.

Uranium Anomaly Descriptions

A summary of the uranium concentrations in the rocks, creek sediments, surface waters, soils and plants is provided as Table 12-2. The size and strength of any anomalies is provided in this table. The sample locations are provided in Figure 12-2.

<u>Uranium Rock Anomalies:</u>

The mineralization in the Tiroroa facies of the Hawks Craig Breccia is reported to be different on the north and south side of the Buller River. To the north of the river the main primary uranium mineral is coffinite. The uranium is interpreted to be epigentic in origin. At least 10 mineralized horizons were reported with values ranging from 0.02 to 5.4 % U .

On the south side of the river, where most of the surface water, sediment and plant sampling was undertaken, the main primary uranium mineral is uraninite. The deposits are reported as having a much wider range of associated sulphides. The only available

information on the uranium levels is on mineral samples which have uranium concentrations of approximately 250 ppm to 150,000 ppm.

The extent of the mineralization was only provided by indications on base maps where radioactive occurrences were discovered in the Tiroroa facies (refer to Figure 12-2). To the south of Buller River two anomalies may be present. For the area north of Buller River only a restricted area nearby Uranium Creek is reported as being radioactive. No mines were specifically delineated, however, it was mentioned that one creek draining into Buller River was contaminated because of mining activites.

Creek Sediment Anomalies:

The creek sediment results are shown in Figure 12-3. The samples were collected from Ohika-iti River and from creeks draining into the south side of Buller River. The concentrations ranged from 0.8 to 13.6 ppm for the first sampling round. A resampling of Tiroroa Creek was undertaken because of the mineralization discovered there and values of 185 to 620 ppm were measured. A threshold value of 3.0 ppm has been picked as a minimum limit for anomalous concentrations. This value is based on approximately two times the low concentrations measured in the areas where no mineralization was reported.

Surface Water Anomalies:

156 water samples were collected from 17 localities along Buller River or tributaries. These results are shown in Figure 12-4. The values range from 0.6 to 2.7 ug/L U. Because of the narrow range in results no anomalies have been outlined.

In an additional study of surface water, uranium concentrations were measured from uranuim adsorbed onto peat that had been placed in creeks. These values, shown in Figure 12-3, ranged from 4.0 to 325 ppm ash. The creek from which the 325 ppm value was measured was listed as having been contaminated by mining activities. Ignoring the 325 ppm value, possible delineation of surface water anomalies (not shown on Figure 12-3) are very similiar to those outlined for the surface water sediments.

Soil Anomalies:

Neither of the two soil studies provided information on the locations of the soil samples. The information from both studies indicates that high uranium concentrations are present with ranges of 2 to 6,000 ppm reported by Cohen et al. (1969) and 100 to 63,850 ppm (on loss on ignition samples) (range of mean concentrations of estimated 38 samples) measured by Whitehead and Brooks (1969b).

Plant Anomalies:

Two studies on uranium concentrations in plants were reported. The uranium concentration in aquatic bryophytes were measured in the first study and these results are provided in Figure 12-5. Bryophytes are used as indicators of the uranium concentrations in the streams in which they grow. Samples were collected from 14 streams (a total of 36 samples). An average of 5 species were collected from each stream. The bryophytes grow in small clumps that contain up to 8 different species. The authors could not readliy separate the different species from the sample and therefore the sample has a composite of species. The values range from 0.7 to 86.0 ppm ash. It is difficult to outline anomalies even though the higher values (i.e. 52.0 ppm, 68.0 ppm, 86.0 ppm) were measured in creeks where radioactive occurrences are reported. This is because similiar concentrations are measured in areas with no radioactivity and in areas with mineralization. The values measured appear to be higher than expected and with the use of a generic threshold value, the majority of the results end up being classified as anomalous. (It is noted that the creek in which mining activity effects were mentioned, had a high bryophyte uranium concentration (i.e. 52.0 ppm ash) but did not have the greatest value.) An estimate of the whole area being anomalous has been included in Table 12-2.

The second study involved the measurement of uranium concentrations in terrestrial plants including bryophytes, ferns, shrubs and trees. The number of samples collected is not indicated. The values mean ranged from 18 to 21,500 ppm ash. The greatest concentration was measured in a monocotyledon. The locations of these samples was not provided and therefore no terrestrial plant anomalies can be determined.

TABLE 12-1
URANIUM CONCENTRATIONS AT LOWER BULLER GORGE REGION, NEW ZEALAND

Sample #	Surface Water ppm peat ash[1] ug/L[2]	Creek Sediment ppm	Plant ppm ash
1		3.4(3)	
2		8.6(3)	
3		2.4(3)	
4		2.0(3)	
5		1.2(3)	
6		4.3(3)	
7		4.5(3)	
8		3.4(3)	
9		1.6(3)	
10		0.8(3)	
11		3.4(3)	
12		1.5(3)	
13	10.5(1)		14.3(1)
14	18.6(1) 2.76(2)		19.9(1)
15	18.6(1) 1.95(2)	8.6(3)	16.8(1)
16	9.3(1)		8.8(1)
17	9.4(1)		12.1(1)
18	9.0(1) 1.19(2)	0.8(3)	4.7(1)
19	57.0(1)	2.9(3)	11.2
20 (contaminat.?)	324(1)		52.0(1)
21	15.6(1)		12.8(1)
22	18.3(1)	13.6(3)	18.7(1)
23	33.0(1)		68.0(1)
24	36.0(1)		86.0(1)

Sample #	Surface Water ppm peat ash[1] ug/L[2]	Creek Sediment ppm	Plant ppm ash
25	75.0(1) 0.68(2)		6.0(1)
26	1.23(2)	1.4(3)	
27	1.02(2)		
28	0.85(2)		
29	1.53(2)		
30	0.8(2)		
31	1.06(2)		
32	0.96(2)		
33	1.95(2)		
34	0.96(2)		
35	4.0(1) .55(2)		0.7(1)
36	.8(2)		
37		1.7(3)	

(1) Whitehead and Brooks (1969a)
(2) Wodziki (1959)
(3) Cohen et al. (1969)

TABLE 12-2 URANIUM CONCENTRATIONS AND ANOMALIES AT LOWER BULLER GORGE, NEW ZEALAND

MEDIA	CONCENTRATIONS	ANOMALIES
ROCK:		
Tiroroa Facies (sandstone) -uranium bearing horizons, mineralization north and south of Buller River	n = unknown	no systemic sampling
1) North:	0.021 - 5.4 % (north)	0.7 km long, along a line (north)
2) South:	250 - 150,000 ppm (south)	2 anomalies (south) a) 1 km^2 (1.4 x 0.7 km^2) b) 2.4 km^2 (1.7 x 1.4km^2)
CREEK SEDIMENTS:		
1) Ohika-iti River and creeks draining into south side of Buller R.	n=18(?) sites=18 0.8 - 13.6 ppm	threshold approx 3.0ppm 4 anomalies (total 3.6 km^2) a) 0.5 km^2 (estimate) b) 1.0km^2 (1.4 x0.7km^2) c) 0.7 km^2 (estimate) d) 1.4 km^2 (1.4 x 1km^2)
2) Resampled Tiroroa Creek	n = ? 185 - 620 ppm	no details on location, high anomaly
SURFACE WATERS:		
1) Creeks draining into southside of Buller River and Hawks Craig River	n=156 sites=17 0.6 - 2.76 ppm	no anomaly defined
2) uranium adsorbed onto peat placed in creeks draining into southside of Buller River	n=36 sites=14 4.0 - 325 ppm ash	est. threshold @ 10 ppm, anomalies overlap with stream sediments'

AQUATIC BRYOPHYTES:		
From creeks draining into southside of Buller River	n=36 sites=14 0.7 - 86.0 ppm ash	not defined, estimate b.g. = 0.7 ppm anomalies 2 ppm 1 km^2 (3.4 x 0.3 km^2)

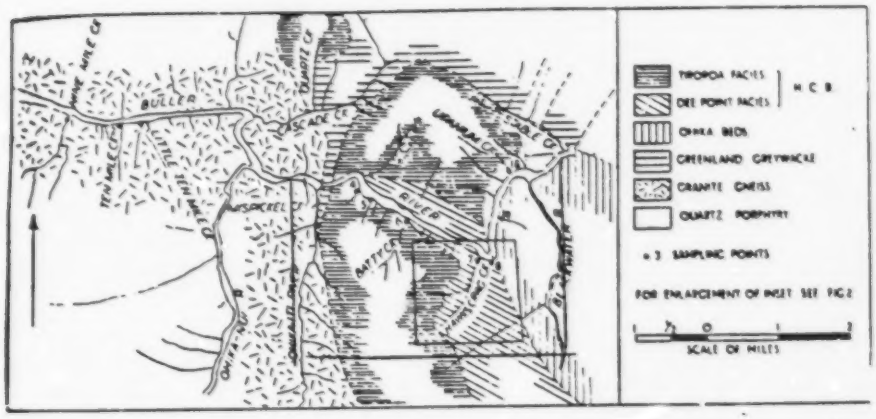


Figure 12-1

Lower Buller Gorge, New Zealand

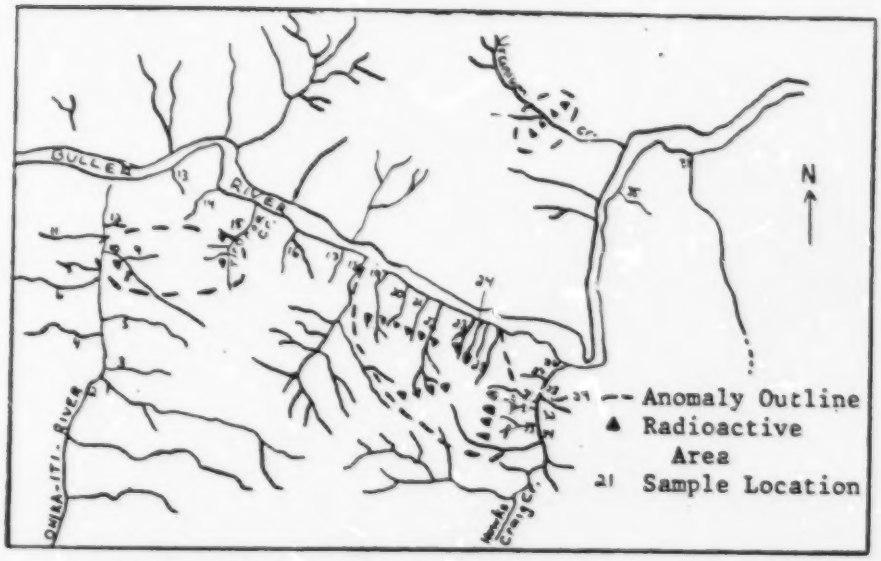


Figure 12-2 Sample Locations

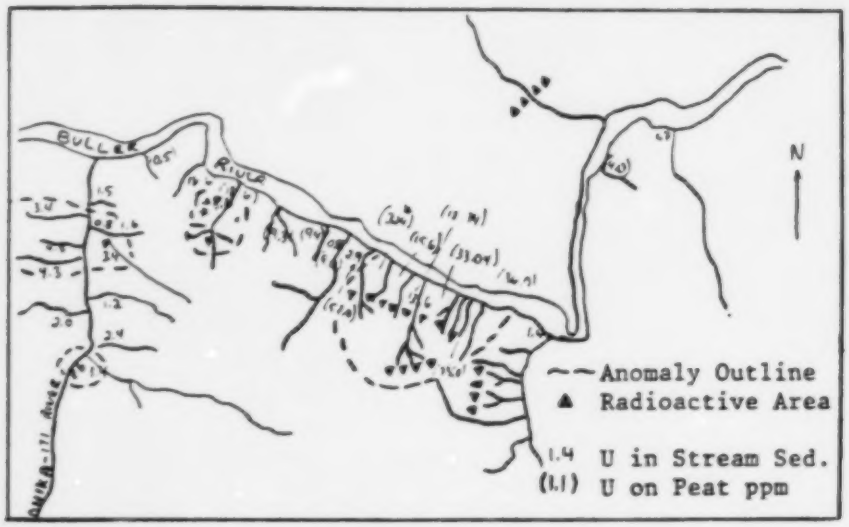


Figure 12-3
Uranium Concentrations
in Stream Sediments
and adsorbed on Peat

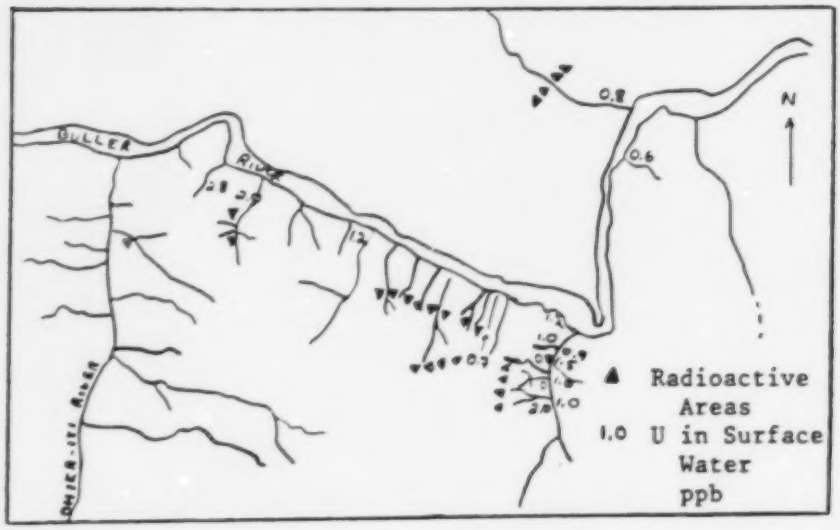


Figure 12-4
Uranium Concentrations
in Surface Waters

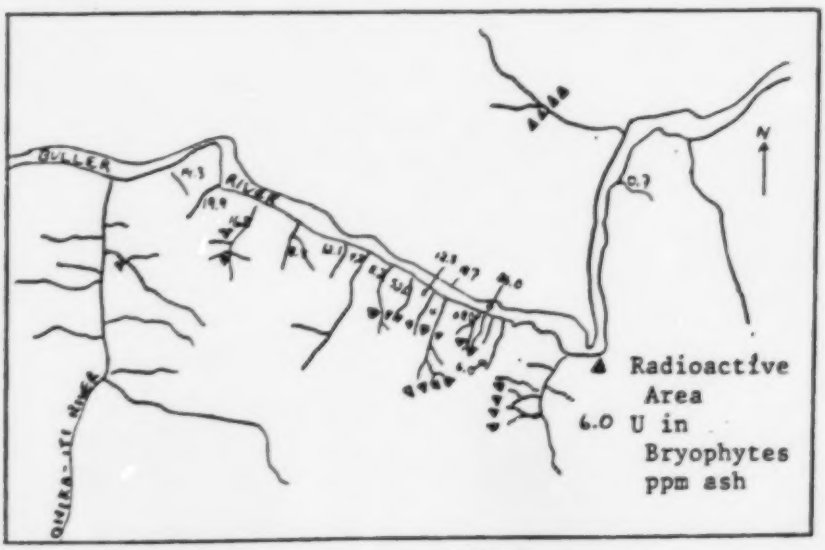


Figure 12-5
Uranium Concentrations
in Bryophytes

SITE 13
KOPRUBASI AREA, TURKEY

References

King, J., Tauchid, M., Frey, D. et al. 1976. Exploration for Uranium in Southwestern Anatolia. In: Proceedings on Exploration of Uranium Ore Deposits, Vienna, 1976, IAEA, pp. 501 - 529.

> The study provides results of exploration studies aimed at locating unoxidized ore in the reduced zone below the water table.

Site Descriptions

The location of the project area is shown in Figure 13-1. Within this large area (3000 square kilometres), the exploration activity centered on the Koprubasi study area which is approximately 250 square kilometres in size (Figure 13-1). An even more detailed study was carried out in the Killik area (further details provided in the soil anomaly section) and the Ecinlitas area (further details provided in the groundwater anomaly section). The area is characterized by a generally mature topography that is locally deeply incised by youthful streams. The climate is mediterranean with 45 cm/yr of precipitation that occurs mostly in the winter and spring.

Known oxidized uranium deposits have been found in sandstones in the lower unit of Neogene sediments. The deposits are derived largely from outside their local basin with their principal provenance being the metamorphic terrain.

Uranium Anomaly Description

The results of the uranium assesment in rocks, stream sediments, groundwaters and soils are provided in Table 13-1.

Rock Anomalies

Refer to Table 13-1.

Stream Sediment Anomalies

Contours of the sediment results are shown in Figure 13-2. All known uranium deposits and occurrences (except one) were indicated by the stream sediment survey.

Groundwater Anomalies

Contoured results of groundwater samples collected within the Koprubasi basin are provided as Figure 13-3. Little difference was noted between spring samples and shallow well samples (less than 16

metres in depth). The uranium content of water from metamorphic terrain was slightly lower than from the Neogene sediments. There is general agreement on a broad scale between the sediment results and the groundwater results.

The results of a detailed survey of water wells from the Ecinlitas area is provided as Figure 13-5. This area was selected based on the 202 ppb well water results from the regional study. Only 50 ppb contours are provided as indication of the results. Based on these survey results, a drilling program was initiated and encountered below the water table 0.11 % eU in 5.9 m of a drill hole.

Soil Anomalies

Contoured results of a detailed soil study of the Killik area are shown in Figure 13-4. This area was picked because of mineral occurrences and anomalies delineated from the ground reconnaissance surveys. The soil anomaly in the western portion of the figure is near a site where a 8.2 metre thick 0.04 % eU was intercepted in a drill hole below the water table. No further details were provided.

TABLE 13-1 URANIUM CONCENTRATIONS AND ANOMALIES AT KOPRUBASI AREA, TURKEY

MEDIA	CONCENTRATIONS	ANOMALIES
ROCKS: 1) Koprubasi study area 256 km^2 (16 km x 16 km) uranium is found in sandstones, prospecting for deep reduced deposits, 2) Ecinilitas area, 2 km^2 (2 km x 1km) arbritary unit 10 m thick at a depth, of 90 m contoured on the basis of gamma logs of drill hole	9 surface deposits in oxidized zones, range from 11 to 360 tons, and grades from 0.03 to 0.05 % n = 16 contoured from 50 - 1000 counts/s	good overlap with groundwater anomalies 3 areas with greater than 200 counts/s, not enough data for useful delineation of size of anomalies
STREAM SEDIMENTS: sampled at 0.75 km intervals within the 256 study area, - 80 mesh samples	n = 1698 <3 - 34 ppm	b.g. 0.5 ppm anomalous >2.2 ppm results were contoured (using 3 ppm contour as indication of anomalies) 11 anomalies all less than 0.5 km^2

GROUNDWATERS:		
1) shallow dug wells (max. depth 16 m) and channeled springs 1 sample per 2 within the 256 km^2 study area, reported that at this sample density only useful for broad reconnaissance information	n = 230 (175 wells, 45 springs) wells: arit. mean 9 ppb 2 - 292 ppb springs: ar. mean 3 ppb 2 - 32 ppb	wells: b.g. 2 ppb anomal. >22 ppb springs: b.g. 2 ppb anomal. >17 ppb results were contoured (using 30 ppb contour as indication of anomalies) 7 anomalies; 6 less than 0.25 km^2, 1 with 1.5 km^2 area
2) Ecinlitas area where maximum value of 3.9 ppm was found in stream sediments and max. value in well water was 292 ppb up to 10 wells/km^2, study area approx. 2 km^2 (2 x 1 km^2)	n = ? results outlined for values greater than 40 ppm	4 areas outlined with values greater than 40 ppm (total area approx. 0.5 km^2) a) 0.3 km^2 (1.2 x .2 km^2) b) 0.1 km^2 (.5 x .5 x 5 km^2) c) 2 areas of 0.05 km^2 (.1 x .15 km^2) anomalous levels of uranium found later in rock at depths of 50 and 100 m, ore hole found in largest g.w. anomaly (5.9 m of ore 0.11% eU

SOILS:		
follow-up work undertaken at Killak based on stream sediment anomaly of 5.2 ppm study area 4 km^2 (2.3 x 1.8 km^2),		
1) gamma radioactivity	n = ? (maybe 50)	all contoured areas = 150 counts/s within study area anomalous bedrock zones encountered at depths of 50 and 100 m
2) chemical uranium in soil	n = ? (maybe 50) contours 3, 10 ppm	b.g = 1.5 ppm anomalous 3 ppm, 1 general area 0.85 km^2 (1.7 x 0.5 km^2)

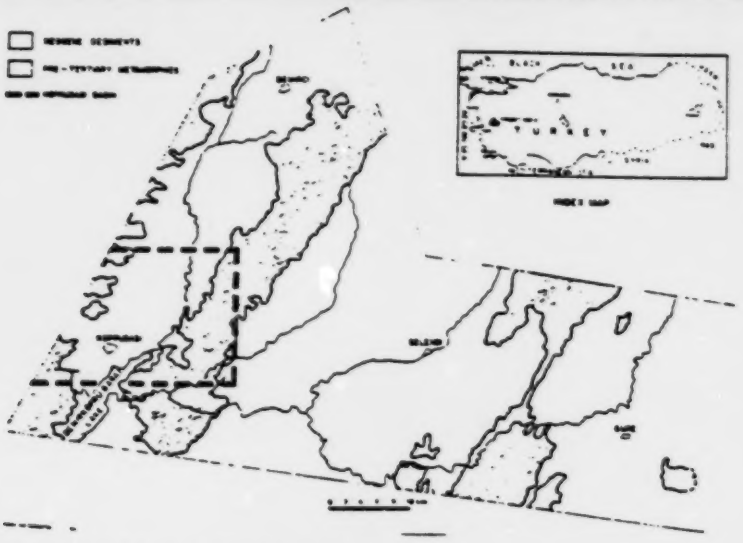


Figure 13-1 Site Location, Koprubasi, Turkey

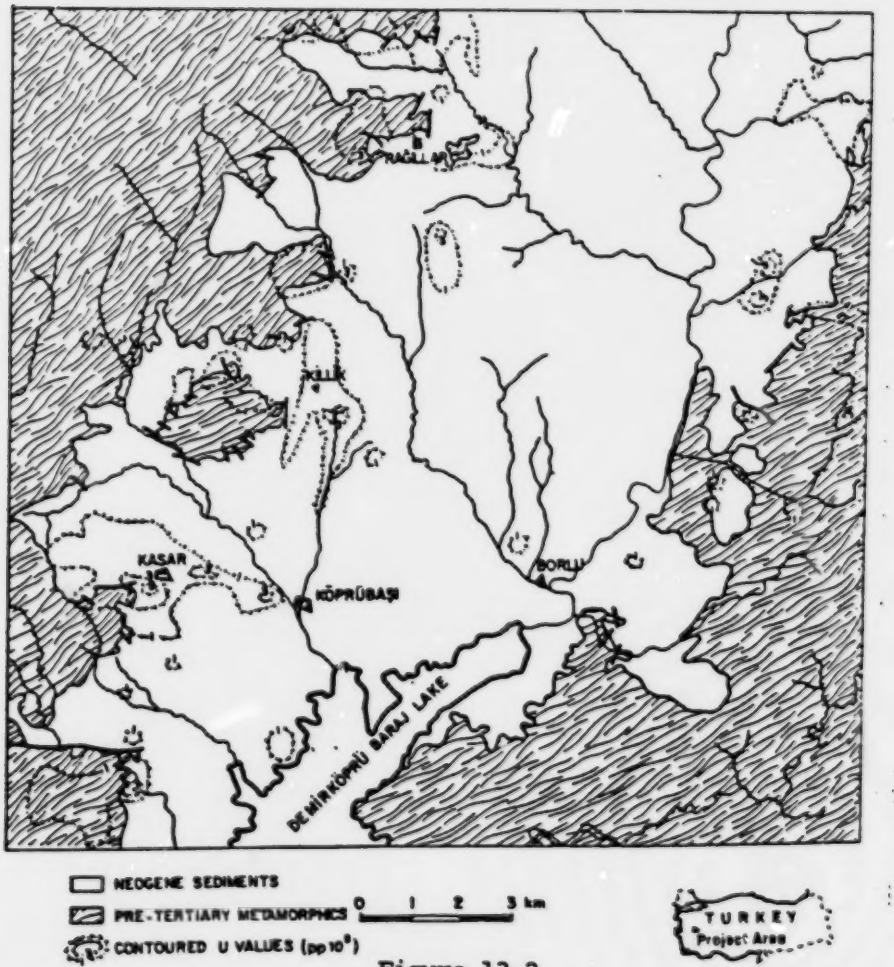


Figure 13-2

Uranium in stream sediments, Köprübasi basin.

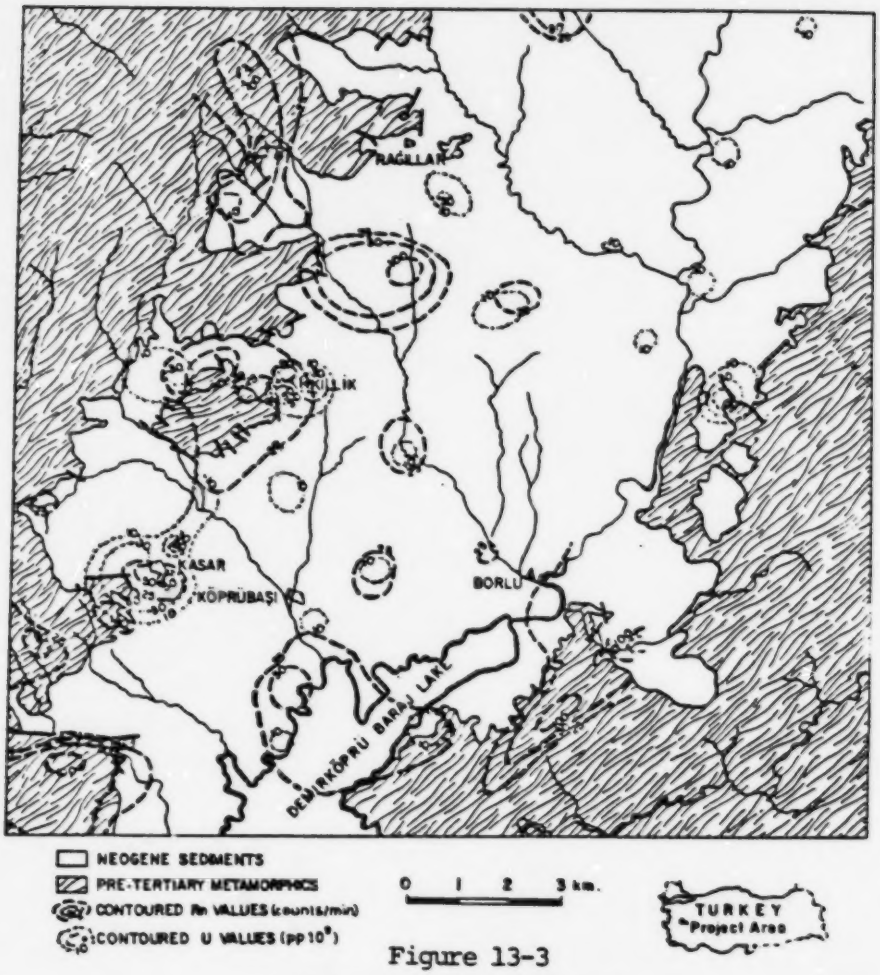


Figure 13-3

Uranium and radon in water, Köprübasi basin.

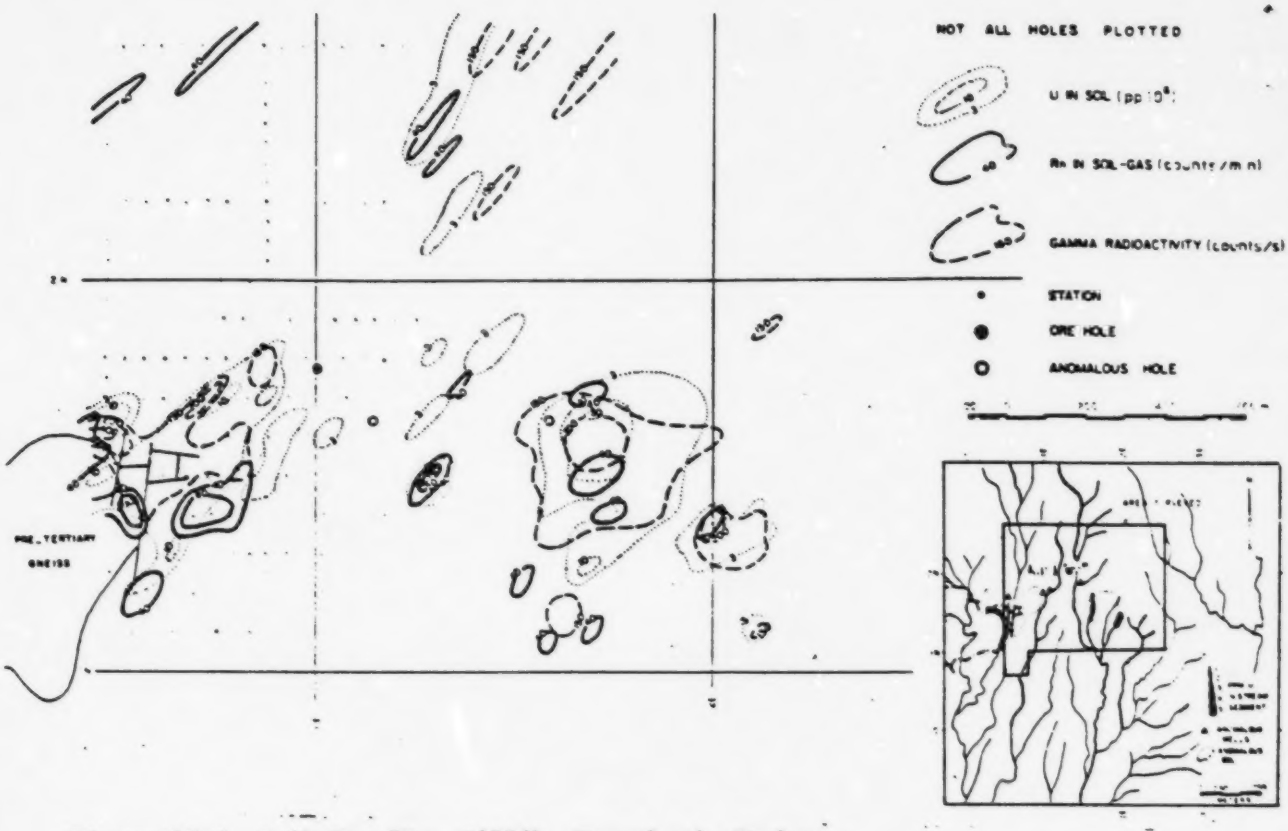
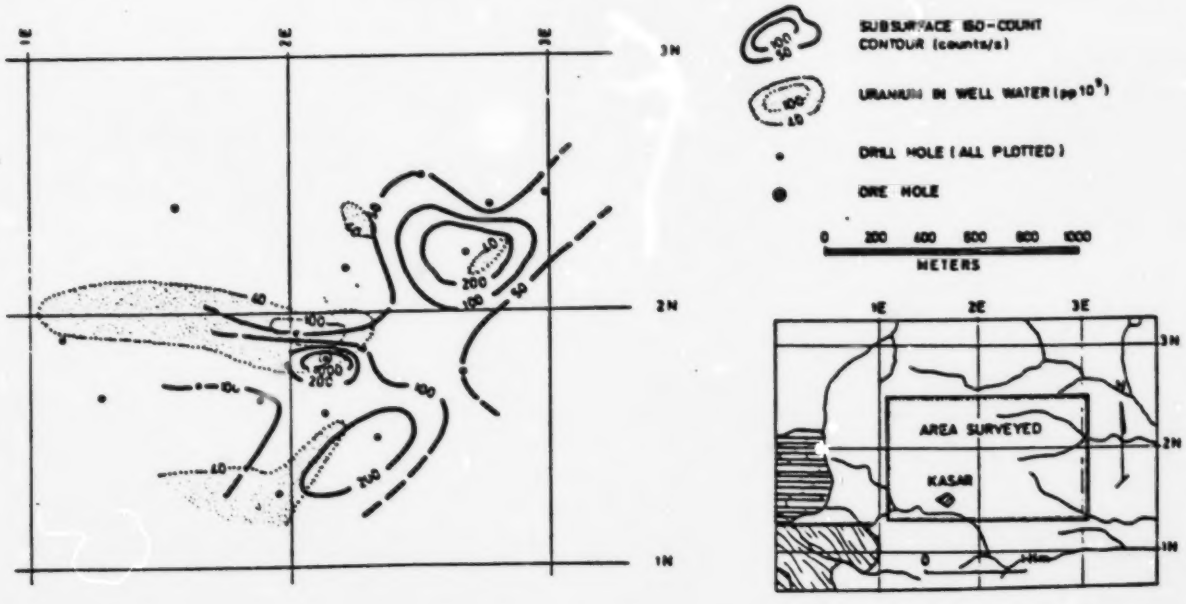


Figure 13-4 Soil Results, Killik, Koprubasi, Turkey

Figure 13-5 Groundwater Results, Encinlitas, Koprubasi, Turkey



SITE 14
YELLOW CAT AREA, UTAH

This site has been included because the unusually large amount of information on uranium concentrations in plants.

References

Cannon, H.L. 1964. Geochemistry of rocks and related soils and vegetation in the Yellow Cat Area Grand County, Utah. USGS Bulletin 1176 127 pg.

> This is a very detailed study of uranium in plants and also in soils and groundwaters. A large basemap is available with this report but could not be included with the present study. The study aim was to correlate the plant uranium concentrations with mineralized bedrock.

Site Description

The Yellow Cat area is found within the Thompson District of Utah (Figure 14-1). The Thompson District was one of the first uranium-vanadium mining disticts of the Colorado Plateau. The Yellow Cat study area is approximately 15 square kilometres. It is situated in an area of moderate relief (1670 to 1770 m.a.s.l.) on the Yellow Cat Mesa. The climate is semi-arid with a deep water table, no water wells, no perennial streams and nonpotable springs. There is a sand cover with little or no profile development. The soils are reported as being alkaline. The type of vegetation occurring is dependant on the availability of water; there is a juniper cover in areas with sufficient water and xerophytic shrubs (plants that utilize moisture from the vadose zone) in areas with less water.

The geology of the area is sedimentary with primarily sandstones and shales exposed (Salt Wash sandstone member overlying Brushy Basin shale member of the Morrison Formation). The ore deposits are in 5 sandstone beds of the Salt Wash member. These beds outcrop at the base of an escarpment. The ore deposits are found above and below the water table. The orebodies contain from 100 to several 1000 tons of ore. This area was mined for uranium and radium from 1911 to 1923, for uranium in 1939 to 1944 and reopened for uranium mining again in 1948.

Uranium Anomaly Descriptions

A summary of the uranium concentrations in the rocks, soils and plants is presented in Table 14-1. The extent of any anomalies is provided is this table. Information on uranium levels in some springs is provided in the text.

Uranium Rock Anomalies:

Refer to Table 14-1.

Spring Anomalies:

The arid nature of the area does not allow for significant surface water sampling, however the author did provide some uranium values for springs. It was noted that these springs drain uranium mines that have been in existance for many years. The two samples have values of between 0.2 and 0.8 ppm. One other sample, from a seep, had a uranium concentration within this range.

Soil/Overburden Anomalies:

In this area it was stated that talus colluvium from the base of the Yellow Cat Mesa was more suitable for sampling than stream sediments. This was because the streams were thought to be contaminated from the mining in the area. The results showed that the colluvial samples were useful for prospecting for ore. Refer to Table 14-1 for further information.

Plant Anomalies:

This study used plant analyses to determine uranium concentrations in rocks as the roots of the plants extend through the dune sand cover and into the underlying ore horizons. No figures on the uranium data are included because the map provided with Cannon's (1964) report is too large and unsuitable.

URANIUM CONCENTRATIONS AND ANOMALIES AT YELLOW CAT AREA, THOMPSON DISTRICT, UTAH

Media	Concentrations	Anomalies
ROCK:		
1) study area 15.4 km^2 (2.4 x 6.4km^2) ore deposits in Salt Wash Sandstone in mining area (from 1911 to 1964)	example concentrations 1) unmineral. n = 87 avg. 13 ppm, 1 - 30 ppm 2) mineral. n = 167 avg. 183, 40 - 80 ppm 3) ore n = 58 avg. 3,800 ppm, 40 - 22,300	ore bodies tabular, elongate masses occur in ground water channels max. 3.7 m thick and 1.5 - 61 m long
2) for comparison with soil and plant results a smaller area is examined (Yellow Cat Mesa), 0.3 km^2 (640 m x 490 m^2)	ore bodies by defintion >840 ppm U within 30 m of largest mining area (a) barren, mineralized and ore bearing drill holes encountered	4 mining areas along eastern edge of study a) 0.002 km^2 (12x168 m^2) b) .0004 km^2 (9 x 46 m^2) c) .00018 km^2 (6 x 30m^2) d) .0003 km^2 (9 x 36 m^2)
Soil/Overburden		
colluvial samples collected around base of Yellow Cat Mesa (0.3 km^2), samples collected at 30 m intervals	n = 61 <1 - >10.0 ppm max. 61 ppm (below mine)	b.g. 0.5 ppm values 2.0 ppm or more restricted to mining areas, other sites contained <2.0 ppm except one area 115 m long having values ranging from >2 to 21ppm

PLANTS: for Yellow Cat Mesa area (0.3 km^2) collected end branches shadscale saltbush (xerophyte)	n = 136 0 - >3.0 ppm ash max. 22 ppm ash	b.g <0.6 ppm ash anomaly (>2.0 ppm) 0.45 km^2 (100 x 500 m^2), between 3 mining areas

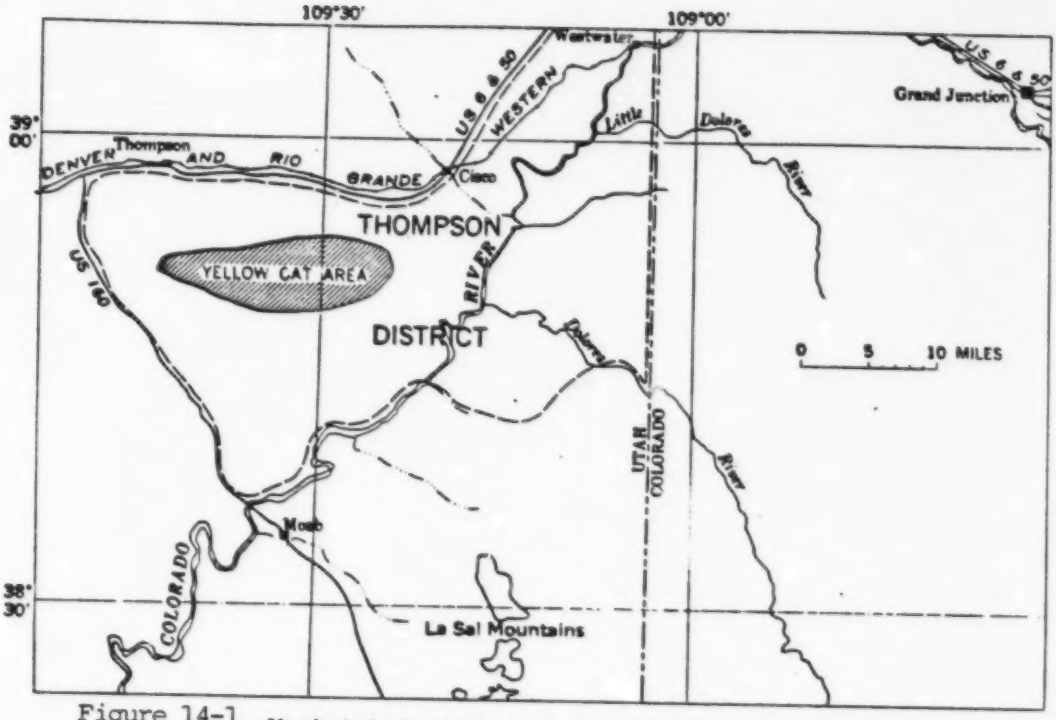


Figure 14-1 .--Map showing location of Yellow Cat area, Thompson district, Grand County, Utah.